United States Department of Agriculture
Forest Service
Idaho Panhandle National Forests
1201 Ironwood Drive
Coeur d'Alene, ID 83814

Reply to: 2630
2520

Date: April 14, 1987

Subject: Review of possible timber harvest effects on fish habitat and channel conditions due to increases in peak flow and water yield.

To: Nick Gerhardt, Forest Hydrologist
Nez Perce National Forest
Box 475
Grangeville, ID 83530

Well, I've finished my review of possible effects of timber harvest on fish habitat due to increases in peak flow.

I want to thank you for your helpful assistance. Your thoughtful review of the draft resulted in several changes which I believe significantly enhanced the quality of the final. I sincerely appreciated your interest and help, and hope the review will be of use to you.

Bob

ROBERT P. RAINVILLE
Fishery Biologist

United States Department of Agriculture | Forest Service | Idaho Panhandle National Forests | 1201 Ironwood Drive Coeur d'Alene, ID 83814

Reply to: 2630 Fish Habitat
2520 Watershed Protection and Management

Date: February 12, 1987

Subject: The Effect of Timber Harvest on Fish Habitat and Channel Conditions Due Increases in Water Yields and Peak Flows.

To: Forest Supervisor

The effect of timber harvest on water yields and peak flows has been a controversial issue on the Forest. Loss of stream channel stability and degradation of fish habitat have been assumed to be associated with timber management induced increases in water yields and peak flow events. As a result, timber harvest has been modified or restricted to minimize the likelihood of damage. Channel work has also been pursued to better enable channels to handle the projected increases in flows resulting from timber harvest.

A Water Yield Model adapted by Isaacson (1977) from a Regional Model and a Channel Stability Analysis Procedure developed by Pfankuch (1975) have served as the basis of water yield concerns and management recommendations. Since the development of these management tools, there has been a significant increase in information on timber harvest induced changes in flow regimes and their influence on channel conditions affecting fish habitat.

Due to concerns regarding water yield increases and the availability of new information on the relationships between management and channel conditions, Ron Prichard requested that I prepare an analysis to update our understanding of the effects of management-altered flow regimes on channel conditions affecting fish habitat (Ron's memo is in the Appendix).

I adopted the following objectives based upon Ron's request:

1. To clarify possible cause and effect relationships between canopy removal and fish habitat damage arising from changes in stream flows.

2. To evaluate factors other than water yield and peak flow increases as alternative causes of observed changes in channel conditions.

3. To identify aspects of the Water Yield analysis procedure that need updating.

4. To note management practices, constraints, and evaluations which are needed to protect fish habitat and stream channels.

5. To enchance the Management Team's understanding of the complex relationships between management activities and fish habitat quality.

The influence of management activities on channel conditions due to water yield or peak flow increases is a controversial topic among watershed authorities. There is a lot of information available, but to adequately evaluate possible effects requires long-term, well-controlled studies. To date no such work has been completed. So conclusions are drawn from smaller scale studies which generally consider single relationships under a specific hydrologic setting. Some relationships have received little or no attention.

Because our understanding is still developing, I have relied heavily on several individuals I regard as forest watershed experts. These individuals provided valuable guidance and criticism. Their contributions have significantly enhanced the quality of this paper. General draft review comments are located in the Appendix, and I have copies of specific comments. Most of their suggestions were made in the final.

	Assistance Provided	
	Data	Review
Don Bartschi, Region 1 Fisheries Program Manager, USDA Forest Service		X
Dr. Bob Beschta, Hydrologist, College of Forestry, Oregon State University	X	X
Bob Embry, Forest Hydrologist, Idaho Panhandle National Forest		X
Dr. Fred Everst, Fishery Biologist and Acting Project Manager, USDA Forest Service, Pacific Northwest Research Station		X
Dr. Henry Froehlich, Hydrologist, Oregon State University	X	X
Nick Gerhardt, Forest Hydrologist, Nez Perce National Forest		X
Dr. Gordon Grant, Research Hydrologist, USDA Forest Service, Pacific Northwest Research Station	X	X
Dr. Dennis Harr, Supervisory Research Hydrologist, USDA Forest Service, Pacific Northwest Research Station	X	X
R. Alan Issacson, Hydrologist, Spokane Community College	X	
Dr. Jack King, Research Hydrologist, USDA Forest Service, Intermountain Research Station	X	
Dr. Walt Megahan, Research Hydrologist, USDA Forest Service, Intermountain Research Station	X	X
*Dave Rosgen, Hydrologist, Wildland Hydrology Consultants		X

	Assistance Provided	
	Data	Review
Bob Schrenk, Timber and Watershed Staff Officer, Idaho Panhandle National Forest		X
Dr. Charles Troendle, Research Hydrologist, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station	X	X

*Dave's criticisms may not have been intended for general review. However, I found his input to be helpful. They provide a perspective that still may not be adequately represented in this paper but which is valid, nonetheless.

In preparing this paper, I considered the Management Team to be the primary audience. Therefore, I've avoided possibly confusing technical jargon. I have also tried to capture the central thought while sacrificing some of the detail. This was a little painful for me. But, although some minor inaccuracies may have resulted, I believe your appreciation of the central ideas will be enhanced.

To address the objectives, a considerable amount of information had to be presented. However, I attempted to capture the major points affecting our management in the Summary and Conclusions and Recomendations sections. The remainder of the report provides greater detail relative to the points presented in these sections and presents the factual justification for their inclusion. Through this effort, I managed to accumulate a considerable library. If after reading the report you would like more specific information, I can make this data available.

Bob Rainville

ROBERT P. RAINVILLE
Fishery Biologist

INDEX

A. SUMMARY

Although documented increases in water yields and peak flows have resulted from canopy removal, there is no evidence indicating that the magnitude of increases is sufficient to directly damage fish habitat or change third order and larger channels. Indirectly, increased discharge may affect larger channels by dislodging instream structures (logs) in headwater channels and thereby releasing the stored sediment, or by causing the saturation and failure of areas with sensitive soils. Sediment resulting from these upslope processes could exceed the transport capabilities of the third order and larger streams and cause channel changes that would be detrimental to fish habitat. Nevertheless, the existence of either the direct or indirect influences has not been adequately assessed in North Idaho.

Although several examples of channel damage on the Forest have been credited to increased water yields, other causes may provide more probable explanations. Increased sedimentation, removal of instream log obstructions, road encroachment, culvert failures, riparian harvest, and early logging practices have all definitely caused channel changes and loss of fish habitat. All these activities and events have occurred on the Forest. Significant channel instability (filling and widening) and loss of fish habitat should be expected where debris removal and road encroachment occur on residual and glaciated Belt streams regardless of management-induced increases in runoff.

Information is needed to better understand relationships between upslope management and effects on downstream beneficial uses. The response of headwater streams to increases in sediment transport and flow needs to be assessed. This is an important linkage which is missing in our understanding. In addition, examples of channel damage need to be evaluated to clarify cause and effect relationships. We also need to refine our channel survey procedures. Quantified assessments of channel parameters are needed to judge the significance of changes and to evaluate effects on beneficial uses.

Although we still have a lot to learn, some management practices have been shown to be key requirements needed to protect channel conditions. Large woody material should generally not be removed from streams, and riparian prescriptions and guidelines need to provide for its replacement. Guidelines are needed to protect the structure of headwater streams. Channel encroachment by roads should be avoided and, wherever possible, existing encroachment should be corrected. Management-related sediment additions to the stream need to be minimized. The most effective methods of sediment control include the use of road closures (including some culvert removal), filter windrows at stream crossings, adequate road drainage, and rolling grades. The avoidance of unstable areas during road and unit location is also critical.

The Water Yield Model and Channel Stability Evaluation procedure should not be used to establish thresholds of fish habitat or channel damage until technical problems are corrected and better supportive information is identified. This model has been a good tool to moderate harvest activities, but key assumptions in the model are not supported by research results and can lead to

misinterpretations by management. An alternative is to use harvest area (less than 25 years old) in excess of 25 to 30% of headwater drainage areas and soil compacting activities (roads, skid trails, landings) in excess of 5% of headwater drainages as thresholds that would trigger quantified channel surveys and technical assessments of channel conditions. The surveys and assessments would be used to provide input for environmental assessments and to evaluate basic relationships between channel conditions and management. (A description of this approach is in Section E.3, on page 30.)

B. KEY RELATIONSHIPS BETWEEN CANOPY REMOVAL AND POSSIBLE CHANNEL DAMAGES

To evaluate the validity of water yield concerns, we need to be familiar with the cause and effect relationships between timber harvest, increased runoff, and channel conditions. The following is a summary of these relationships and data which support or contradict each point.

1. The Relationship Between Canopy Removal and Snow Accumulation.

Several studies have documented an increase in snow accumulation on sites where the canopy has been removed (Table 1). Snow accumulation on harvested sites will increase by 10 to 60 percent dependent upon the basal area removed, the shape and size of the opening, and the orientation of the opening to wind and sunlight (Anderson 1967, Haupt 1979b, Beschta and Froehlich 1983, Troendle and King 1985). The smallest increases have been noted in stands that have been harvested selectively or with large clearcut units on south slopes. The largest increases were observed on north aspects. In general, increases in water equivalent have been proportional to the basal area removed; however, the relationship is highly variable.

The mechanisms responsible for the increases within harvest units are differential deposition of snow in the drainage and the elimination of snow interception by the canopy. Canopy openings serve as snow traps. Wind patterns are modified by the altered canopy, so that more snow is deposited in the openings and less on forested areas (Haupt 1979b, Troendle 1982, 1986, Megahan 1983, Troendle and Meiman 1984). Anderson and Gleason (1960) estimated that about half of the increase in peak water equivalents noted in clearcuts was due to wind redistribution. Snow accumulates most noteably along the margins of openings where it is shaded by adjacent stands. Because of this edge effect, the largest relative increases in snow accumulation have been observed in narrow strip clearcuts.

Removal of tree cover also reduces or eliminates snow interception (Gary and Troendle 1982, Troendle and Meiman 1984, Troendle and King 1985, Gary and Watkins 1985). Approximately 10 to 30 percent of snow falling on a mature conifer stand is intercepted by the canopy (Anderson et al. 1976, Haupt 1979 a,b). Much of this water may not become part of the snow pack.

On wet low elevation snow packs, intercepted snow may be lost by thawing, dripping and becoming part of the winter outflow (Satterlund and Haupt 1972, Beaudry and Golding 1983, Berris and Harr, draft). Smaller amounts of intercepted snow may be lost by sublimation. Overall a 10 to 30 percent increase in snow accumulation has been attributed to a reduction of interception loss (Anderson 1969, Golding 1982, Troendle and King 1985).

The duration of harvest effects on snow accumulation depends on site specific conditions. Some reduction has been noted within 10 years, but up to an 80 year old stand may be needed before the effect is entirely eliminated (Ziemer 1986, Lull and Reinhardt 1967, Anderson 1969, Megahan 1972, Anderson et al. 1976, Harr 1976, Toews and Wilford 1978, Troendle and King 1985).

An important point is that the objective of most of the research cited has been to maximize increases in accumulation. Narrow strip clearcuts or small block units have been used. Increases in snow accumulation on 30 to 40 acre units should be less due to a reduced edge effect and an increase in sublimation (Anderson and Gleason 1960, Beschta and Froehlich 1983, Megahan 1983).

Table 1. A Summary of Research Work on the Effects of Timber Harvest on on-site Peak Water Accumulation. Studies are Grouped by Type of Harvest and Location.

Study	Type of Harvest	Increase in Peak Water Equivalent	Location of Study
Haupt (1979 a,b)	Strip clearcuts.	56% north slope 37% south slope	Idaho
Megahan (1983)	Clearcut.	41%	Idaho
Golding and Swanson (1978)	Clearcut.	43-45%	Alberta, Canada
Rothacher (1965)	Strip clearcut.	35%	Oregon
Anderson (1969)	60% tree removal strip clearcutting.	43%	California
Anderson (1967)	60% clearcut harvest.	30 to 40%	California
Anderson and Gleason (1960)	Strip clearcut.	35%	California
Anderson and Gleason (1960)	Block clearcut.	25%	California
Brendt (1961)	Clearcut.	29%	Colorado
Troendle (1986)	Clearcut.	22%	Colorado
Troendle (1986)	Clearcut.	30%	Colorado
Wilm and Dunford (1948)	Clearcut.	30%	Colorado
Brendt (1965)	Clearcut blocks.	40%	Wyoming
Weitzman and Bay (1959)	Shelterwood black spruce.	28% (max.)	Minnesota
Weitzman and Bay (1959)	Clearcut strip.	60% (max.)	Minnesota
Weitzman and Bay (1959)	Clearcut block.	80% (max.)	Minnesota

Study	Type of Harvest	Increase in Peak Water Equivalent	Location of Study
Anderson and Gleason (1960)	Selective harvest.	13%	California
Troendle (personal communication May 30, 1986)	Group selection harvest.	18%	Colorado
Troendle & Meiman (1984)	36% basal area removed with partial cutting.	14% increase	Colorado
Brendt (1961)	Selection harvest.	6%	Colorado
Goodell (1952)	52% selection harvest.	24%	Colorado
Goodell (1952)	50% group selection harvest.	17%	Colorado
Wilm and Dunford (1948)	Selection harvest.	31%	Colorado
Weitzman and Bay (1959)	Single tree selection black spruce.	40% (max.)	Minnesota
Wilm and Dunford (1948)	Heavy thinning, young lodgepole (4,400 to 630 trees/acre).	23%	Colorado
Wilm and Dunford (1948)	Light thinning, young lodgepole (4,400 to 2,000 trees/acre).	17%	Colorado

2. <u>The Relationship Between Harvest-Related Changes in Snow Accumulation, Evapotranspiration, and Melt Rates and Increased Water Yields and Peak Flows</u>.

Increases in water yields following timber harvest have generally been noted (Table 2). Water yield increases are associated with reductions in evapotranspiration and canopy interception (Megahan 1972, Anderson <u>et</u> <u>al</u>. 1976, Troendle 1986, 1982, Troendle and King 1985, in press). The magnitude of increase is related to the basal area removed (Reinhart <u>et</u> <u>al</u>. 1963, Rothacher 1970, Megahan 1976, Toews and Wilford 1978, King, draft, Troendle, in press). About 20 to 25 percent of the basal area must be removed before increases can be detected (Douglass 1967, Rothacher 1971, Megahan 1976, Troendle and Leaf 1980, Bosch and Hewlett 1982). Maximum increases have been observed with strip clearcuts on north slopes where units were located next to streams, and where regrowth was inhibited by hot burns or herbicides (Kittredge 1953, Anderson 1966, Anderson <u>et</u> <u>al</u>. 1976). The magnitude of the increase is significantly influenced by precipitation, with the greatest relative increases occurring during "wet" years (Leaf 1975, Bosch and Hewlett 1982, Troendle 1983, 1986, Ponce and Meiman 1983, Troendle and King 1985, in press).

Peak flow increases have also been observed in several studies (Table 2). Greater snow accumulation, faster melt rates, and increased soil moisture in clearcuts are the primary factors generally associated with increases (Anderson and Gleason 1960, Anderson 1960, Megahan 1972, 1976, Beaudry and Golding 1983, Troendle and King 1985, Troendle 1986, Harr 1986, Berris and Harr, unpublished draft). Smith (1980) has noted the potential significance of ice lens formation in clearcuts which can cause rapid water run off. Hot burns may also enhance peak flows if regrowth and soil infiltration are reduced (Anderson <u>et</u> <u>al</u>. 1976). The most significant peak flow increases have been noted where large percentages of small drainages have been harvested with large clearcuts (Megahan 1976).

Peak flow responses to canopy removal have been highly variable and inconsistent (Harr 1976, Megahan 1976). Topographic, geologic, and climatic differences are at least partially responsible for this inconsistency. However, other factors have been detected which further complicate the relationship between harvest and peak flows. Canopy removal may only affect low to moderate runoff events (Harris 1973, Harr 1976, Megahan 1976). None of the reviewed studies have noted significant increases in peak events with return intervals over about 5 years (Rothacher 1973, Harr 1976). Another source of variation is road density. Roads may increase peak flows (Harr 1976, Harr <u>et al.</u> 1979, Megahan 1972, 1983). Harr (1976) noted increases in peak flows in a drainage where 12 percent of the area was occupied by roads, skid trails or other soil-compacted areas. Because roads may affect peak events with a return interval longer than 5 years (larger events), they and other soil-compacted areas may have a greater influence on management-induced increases than canopy removal alone (Harr 1976).

Table 2. A summary of research work on the effects of timber harvest on water yields and peak flows. Studies are grouped by species type and harvest treatment. They are listed in order of decreasing harvest.

Study	Location	Drainage Size (acres)	Tree Species	Treatment	Average Water Yield Increase	Peak Flow Increase
Troendle (1986)	Colorado (Wagon Wheel Gap)	200	Conifer/ Aspen	100% Clearcut	16%	50% (Annual Peak)
Rothacher (1973)	Oregon	237	Conifer	100% Clearcut	34%	30% (Average Peak)
Harr (1976)	Oregon	124	Conifer	100% Clearcut	70%	
Harr et al. (1975)	Oregon	40	Conifer	90% Clearcut		30% (Average Peak)
Harris (1973)	Oregon	175	Conifer	82% Clearcut	27%	
Anderson (1952)	Oregon		Conifer	45% Clearcut		30%
Troendle and King (1985)	Colorado (Fool Creek)	714	Conifer	40% Strip Clearcuts	40%	23% (Daily Peak)
Troendle and King (in press)	Colorado (NF Deadhorse Ck)	100	Conifer	36% in 5 Acre Clearcuts	36%	50% (Annual Peak)
				40% Basal Area Removed Partial Cut	36%	
King (draft)	Idaho	207	Conifer	37% Clearcut	79%	14% (Instantaneous)
King (draft)	Idaho	213	Conifer	34% Clearcut	52%	59% (Instantaneous Annual)
Harr (1976)	Oregon	250	Conifer	33%, 7 to 10 Ac. Clearcuts	17%	
Harr (1976)	Oregon	168	Conifer	30% Patch Clearcuts	24%	
Harr (1976)	Oregon	170	Conifer	30% Shelterwood	0	
King (draft)	Idaho	154	Conifer	29% Clearcut	79%	34% (Instantaneous Annual)
Reported in Harr (1976)	Oregon	749	Conifer	25% Patch Clearcut	5%	

Study	Location	Drainage Size (acres)	Tree Species	Treatment	Average Water Yield Increase	Peak Flow Increase
Harr (1976)	Oregon	146	Conifer	25%, 20 to 30 Ac. Clearcuts	0	
Harr (1980)	Oregon	175	Conifer	25% Patch Clearcut	0	
King (draft)	Idaho	70	Conifer	19% Clearcut	74%	49% (Instantaneous Annual)
Reported in Anderson et al. (1976)	Arizona	1,163	Conifer	16% Clearcut	16%	
Christner and Harr (1982)	Oregon	74,870	Conifer	28% Clearcut (below 4,000 ft.)		up to 28%
Harr (1982)	Oregon	29,400	Conifer	14% Clearcut (below 4,000 ft.)		up to 27%
Harr (1982	Oregon	138,100	Conifer	31% clearcut (below 4,000 ft.)		up to 56%
Troendle and King (in press)	Colorado (Deadhorse Cr.)	642	Conifer	10%, 5 Acre Clearcuts, Partial Cut	0	0
Reported in Anderson _et_ _al_. (1976)	N. Carolina	40	Mixed Hardwoods	100% Clearcut	40%	
Reported in Anderson _et_ _al_. (1976)	N. Carolina	33	Mixed Hardwoods	100% Clearcut	65%	
Reported in Anderson _et_ _al_. (1976)	New Hampshire	39	Mixed Hardwoods	100% Clearcut	29%	
Reported in Anderson _et_ _al_. (1976)	West Virginia	85	Mixed Hardwoods	100% Clearcut	18%	
Reported in Anderson _et_ _al_. (1976)	Pennsylvania	106	Mixed Hardwoods	20% Clearcut	17%	

Study	Location	Drainage Size (acres)	Tree Species	Treatment	Average Water Yield Increase	Peak Flow Increase
Reported in Anderson *et al.* (1976)	Arizona	318	Conifer	45% Selectively Harvested	0	
Reported in Anderson *et al.* (1976)	Arizona	248	Conifer	32% Selectively Harvested	51%	
Reported in Anderson *et al.* (1976)	West Virginia	38	Mixed Hardwoods	36% Selectively Harvested	5%	0
Reported in Anderson *et al.* (1976)	North Carolina	50	Mixed Hardwoods	27% Basal Area Selectively Harvested	0	
Reported in Anderson *et al.* (1976)	North Carolina	70	Mixed Hardwoods	22% Basal Area Selectively Harvested	5%	
Reported in Anderson *et al.* (1976)	West Virginia	90	Mixed Hardwoods	22% Selectively Harvested	1%	0
Reported in Anderson *et al.* (1976)	West Virginia	85	Mixed Hardwoods	14% Selectively Harvested	1%	0

The influence of harvest on runoff synchronization is another factor which complicates projections of peak flow increases. To increase peak flows downstream, more water must runoff at the same time. However, harvest does not necessarily cause greater synchronization of the runoff. Although increases in the total runoff can be expected during the spring, advancement in the timing of runoff or water storage in the soil, underlying rock, and in the channel may significantly minimize potential increases in peak events (Anderson et al. 1976, Megahan 1972, Chow et al. 1957, Anderson 1966). The larger the drainage area, the less likely synchronization of flows will occur due to the greater opportunity for storage (Megahan 1972). Lack of synchronization may help explain why in many cases increases in water yield have occurred with no increase in peak events (Hewlett and Hibbert 1961, Hewlett and Helvey 1970, Sutterlund and Eschner 1965, Verry 1972).

The duration of water yield and peak flow increases resulting from timber harvest has been estimated. Increases in water yield have been reported to return to preharvest conditions within 5 to 80 years with most authors reporting periods between 15 and 25 years (Megahan 1972, 1976, Anderson et al. 1976, Harr 1976, 1983, Troendle 1982, Beschta and Froehlich 1983). Recovery from peak flow increases are not as well documented. Christner and Harr (1982) estimated 25 years as the time required for on-site recovery in Western Oregon's Cascade Range. Wilford (1984) noted that on-site factors influencing rain-on-snow peaks return to preharvest conditions when regeneration reaches 70 percent crown closure and 8 inches DBH.

In summary, although the effects are highly variable, we should expect increases in water yields and possibly peak flows to result from timber harvest or road construction. Whether these increases are large enough to change channel conditions is the next question we need to consider.

3. <u>The Relationship Between Increases in Water Yield and Peak Flows Resulting from Timber Harvest and Channel Changes</u>.

Stream channel conditions are the result of a dynamic equilibrium related to streamflow, sediment transport, and riparian conditions (Anderson *et al*. 1976, Beschta 1985). The following equations describe how channel attributes are related to changes in flow regimes or sediment transport (Schumm 1971).

$$Qw \sim \frac{b,\ w,\ d}{s} \qquad \text{(Equation 1)}$$

$$Qs \sim \frac{b,\ w,\ s}{d,\ p} \qquad \text{(Equation 2)}$$

where: Qw = mean annual flood or discharge
Qs = bed material transport
b = channel width
w = channel wavelength
d = channel depth
s = gradient
p = sinuosity

Based on Equation 1, if streamflow increases, a channel may respond by increasing depth and/or width (Harr 1981, Beschta 1983, Lyons and Beschta 1983). These changes could result in the scour of streambanks and the accelerated movement of coarse sediment that had been stored in the channel.

The question is whether increases in streamflow resulting from canopy removal are of sufficient magnitude to cause detectable changes in channel attributes. Some authors have speculated that damage could result from timber harvest (Toews and Wilford 1978, Haupt 1979b, Harr 1981, 1976, Christner and Harr 1982, Berris and Harr draft). This is also the central concern in the Water Yield and Channel Stability analysis projections used on the Forest (Galbraith 1973, Isaacson 1977). Based on this model, Isaacson (1977) indicates that when average annual flows are exceeded by more than 10 percent, or average monthly peak flows by more than 20 percent, channel damage will begin to occur.

I have not found any studies which have noted negative changes in third order or larger channels due to harvested-induced or natural increases in streamflow. Lyons and Beschta (1983) studied the response of the Middle Fork of the Willamette River to a large natural flood (1964 event) and to subsequent timber harvest. They reported that flood damage was associated with widening caused primarily by high sediment input and not high flows. Channel reaches which only experienced increased flows did not have detectable damage. Channel widening and braiding was observed only in reaches that received accelerated sediment delivery. After the flood, an increase in timber harvest occurred in the drainage. About 15 percent of the baisin was harvested by 1980. The authors did report management-related increases in peak flows after this period. However, rather than becoming wider, a trend towards decreasing channel widths was noted.

A similar study was conducted on the Kowai River in New Zealand. After studying channel response to a 1951 flood, Beschta (1983) concluded that widening was due primarily to increased sediment loads and not flood discharge.

Two studies evaluated the relationship between timber harvest and channel conditions directly. Assessing the effects of harvest activities on channel morphology, Grant et al. (1984) noted that sediment delivered to channels by axial landslides was the most important factor responsible causing channel widening. They concluded that unless located on sites subject to landsliding, clearcutting alone plays only a minor role in affecting the morphology of downstream channels even after major climatic events. Hess (1984) reported similar results. After evaluating 5 eroded channels, he linked the damage to the dislodgement of woody material in the channel and to mass failures originating from roads, harvest units or undisturbed sites.

Morphologic and hydrologic conditions on third order and larger streams may minimize their vulnerability to harvest-related flow increases. The morphology of most third order and larger stream bottoms tends to minimize the scour of increased flows. Stream channels experience bank full flows about once every 2 years (Leopold et al. 1964, Neilson 1974). They are not abnormal. Flows which exceed the channel capacity flood into the riparian zone. On most of the Forests streams this spilling mechanism reduces the erosion potential of peaks because the water flows over a much wider area containing trees and other obstructions. For flood flows to cause significant channel scour, they would have to be large enough to overcome this energy absorbing system. If canopy removal affects only small to moderate-sized peaks and generally results in less than a 20 percent increase, the increases may be insufficient to overcome this energy absorbing effect.

The size of harvest-related increases in peaks relative to natural variation in peak runoff also make their significance questionable. Generally, increases in peak events resulting from timber harvest have been relatively small, and difficult to detect (Troendle and King in press, Harr 1983, Krutilla et al. 1983, Rothacher 1971, 1973, Harr and McCorison 1979). Through natural variations in flow, stream channels are exposed to changes which far exceed the magnitude of these increases. For example, the peak flow history of Hayden Creek in North Idaho between 1948 and 1981 indicates that the channel has been exposed to annual changes of 350 percent in peak events (Table 3). A system which normally adjusts to 350 percent changes in annual peak flows would likely not become destabilized by even a 30 percent change, particularly if this increase affects primarily low peak events.

Other aspects of timber harvest may have a more significant effect on peak flows than cover removal. Harr (1976) considers soil compaction and roading to have much more serious consequences on peak flows. Significant increases in peaks in Western Oregon have been detected where 5 to 10 percent of the drainage is occupied by roads, skid trails, or other compacted soil areas (Harr 1976, 1979). Because increased flow originating from areas of compacted soil may affect larger peak events, they have a greater potential for channel damage (Harr 1976).

Although most of these factors minimize concerns that harvest-induced increases in flow directly affect third order and larger channels, the indirect effect of increased runoff may be of greater significance. Increased runoff could affect larger channels by scouring smaller, headwater channels or by triggering mass failures. Either effect could significantly affect downstream channels due to accelerated sedimentation.

Headwater channels are especially sensitive to increases in peak events. They are generally more "V" shaped and have less riparian relief to absorb increased flows. They also receive faster delivery of water, have less opportunity for channel storage, and have a greater chance of flow synchronization (Chow <u>et. al.</u> 1957, Megahan 1972, Christner, and Harr 1982).

Not surprisingly therefore, some of the largest relative increases in peak flows resulting from harvest have been noted on smaller, headwater drainages (King draft). These flows could contribute to the destabilization of the headwater channels by dislodging the log drops normally found in these streams. Harr (1981) noted that 10 of 11 debris torrents in headwater channels occurred during rain-on-snow events, indicating that increased flows may be related to loss of stability in these channels. These events may be significant on some geologic types. Increased runoff may also cause mass failures by contributing to the saturation of unstable slopes (Sidle 1985). Swanson and Lienkaemper (1978) noted that 20% of the landslides in a western Cascades basin occurred as in-channel events.

In summary, although there has been speculation on the negative effects of increased peak flows on stream channels, there have been no documented studies to support this cause and effect relationship on third order and larger channels. Rather, the results of some studies and Forest monitoring data tend to minimize the likelihood of channel damage on larger streams. However the possible role of harvest-related increases in peak flows in triggering destabilization of headwater channels or slope failures is of greater concern. The accelerated delivery of sediment resulting from these events could significantly affect downstream channels.

4. <u>The Relationship Between Increases in Water Yield and Peak Flows Resulting from Timber Harvest and Reductions in Fish Habitat Quality</u>.

If increased flows cause the loss of pool habitat failure of undercut banks, dislodging of large woody material, or the widening of the channel, fish habitat quality would suffer. However, there has been no documentation to support the relationship between increased flows and resultant impacts to fish habitat. Based on the discussion in the preceding section, direct impacts to fish habitat are probably unlikely. However indirect effects are possible if increased runoff destabilizes headwater channels or triggers mass failures. The sediment resulting from these events could fill pools, blanket spawning sites, or cause the erosion if undercut banks.

C. **IMPROVEMENTS NEEDED TO MAKE THE FOREST'S WATER YIELD MODEL (GALBRAITH 1973, ISSACSON 1977) AND CHANNEL STABILITY EVALUATION PROCEDURE (PFANKUCH 1975) MORE RELIABLE INDICATORS OF CHANGES IN FISH HABITAT QUALITY AND MANAGEMENT NEEDS.**

1. Beneficial Aspects Needing Preservation.

The Water Yield Model and The Stream Reach Inventory and Channel Stability Evaluation Procedure have been the primary tools used to assess water resource damages resulting from harvest related increases in flows and to develop alternatives for water resource protection. There are aspects of the Model and Evaluation Procedure which have been beneficial to fish habitat management.

a. The Water Yield Model and Evaluation Procedure have resulted in a moderation of management activities in drainages. The overall result has been to moderate timber management activities in third order and larger drainages. Generally, "unrecovered" openings due to harvest are limited to less than 25 percent of suitable timber areas in a drainage. This limitation is similar to management guides developed in other areas (Toews and Wilford 1978, Christner 1982). Although water specialists may disagree on technical aspects of hydrologic response or the absolute percentages involved, I believe there is generally strong support for moderation as a means to reduce the risk of fish habitat loss due to management-related changes.

b. The Model and Evaluation Procedure are based on a logical sequence of assumed events, starting with increased snow accumulation in openings, followed by an advanced melt and finally increased peak monthly flows and yearly water yields. This logical sequence results in a very methodical, documentable process of analyzing impacts. The partitioning of snow accumulation and release by elevation, canopy closure, and aspect accounts for some of the major variables which need to be considered in areas where spring snowmelt dominates seasonal discharge. Such a clear logical linkage from snow accumulation to seasonal discharge allows for refinement as data is collected.

c. The Model and Evaluation Procedure are well-established and accepted on the Forest. They have been the primary water resource analysis tool on the Forest for about 15 years. During this time, they have been accepted by people throughout the organization and used as a standard evaluation procedure in planning timber sale activities. The procedure provides a method to quantify limitations which are many times requested by managers and the public. Lacking such a respected analysis tool, planning timber activities to conform with hydrologic limitations would be more difficult.

2. Weak Aspects Needing Modification or Additional Documentation.

There are also several problems associated with the Model and Evaluation procedure. Some short comings should be expected. No hydrolgic model should be expected to have such a broad documentable basis to be totally reliable on a forest-wide basis. Professional interpretation will always be needed to overcome gaps in our data and to account for site-specific conditions. However some important points in the model and procedure need updating or better documentation. Misinterpretations, poor projections, and even fish habitat damage could result from the continued use of the Model and procedure without refinement.

a. The Model needs supportive documentation on key points. The Model and Procedure are based on the premise that unless maintained below a threshold, increased flows resulting from canopy removal will cause channel damage. Studies support the concept that harvest does increase water yield. However, the key linkage between this increased water yield and channel damage is based on speculation rather than research results. The limitations of a 10 percent increase in average annual flow and a 20 percent increase in average monthly yields are assumptions and not the results of well-documented, quantified assessments. Similarly, key relationships between channel stability ratings and permissable flow increases noted by Galbraith (1973) are undocumented assumptions. Lacking supportive data, the projections of channel changes and fish habitat damage based on the procedure are weak.

   Some relationships in the Model need to be modified so that they better agree with research results. Projections of increased water yields for third and fourth order drainages exceed measured increases even on headwater drainages where all the canopy was removed (Table 2). Also the assumed distribution of water yield increases does not appear to agree with research results (Megahan 1979, Troendle 1983, Beschta and Froehlich 1983).

b. The Model is based on information collected from areas with different physical, climatic, and hydrological conditions than where it is being applied. Most of the research results cited as support for the Model were collected from drainages smaller than 400 acres. Many were located at high elevations or supported primarily deciduous vegetation (Isaacson 1977, Galbraith 1973). This was the only information available at the time the model was developed. Although the concepts of this model might be appliable to small basins in North Idaho, quantified interpretations for larger drainages need calibration. Projections need to be modified to include more recent findings from Oregon, Washington, and Idaho. Also projections need to account for the Forests conditions which are a hybrid between the warm wet snow packs of the Coast and the drier snowpacks of Colorado. These unique conditions are descussed in section C.2.d. below.

c. Model projections of channel damage should be based upon changes in instantaneous flows, rather than water yield and monthly discharge. The conditions we see in channels are related to flows which are large enough to transport bedload sediments and occur frequently enough to affect channel form (Megahan 1979). Based on work done by Leopold et al. (1964) and Neilson (1974), the capacity of most channels are related to the peak flows that occur about once every two years. The transport of deposited sediment is estimated to begin when at least 65 percent of this 2-year instantaneous peak flow is exceeded (Neilson, 1974). Thus researchers concerned about changes in channel conditions resulting from management have been primarily concerned with effects of instantaneous peaks (Harr 1981, Megahan 1979).

A shortcoming of the Water Yield Model is that it is based on annual water yields and peak monthly flows rather than instantaneous peaks. The Model assumes that canopy removal which results in flow rates that exceed 75 percent of average peak monthly flows before harvest will cause channel damage. However, Megahan (1979) points out that this constraint is significantly lower than the 65 percent of the 2 year instantaneous peak which must be exceeded before the transport of deposited sediment is initiated. He cites an example where the Water Yield Model underestimates the flow capable of channel erosion by about 500 percent (8.1 m^3/sec versus 1.6 m^3/sec) and thus predicts a concern over increases that would have an insignificant influence on sediment transport.

Channel conditions and instantaneous peak flows are even more poorly related to the changes in annual water yield predicted by the Model.

d. In North Idaho, the Water Yield Model should be based primarily on winter rain-on-snow events rather than spring snowmelt pattern of runoff. The Water Yield Model assumes a spring snowmelt patterns of runoff. Accordingly, maximum flows are predicted to occur in May and June. The primary factors determining the size of these flows are the amount of snowpack and rate of snowmelt (Anderson 1966, 1969). (Soil moisture content also plays a role but does not appear to be quantitatively accounted for in the Model.) The Model assumes that the snowpack influencing these flows varies by elevation. The largest accumulations are estimated to be on sites above 3,500 feet. The Model also assumes that short wave radiation (sunlight) is the primary factor determining melt rates. Thus snowpacks on exposed south slopes are projected to melt faster than north slopes.

These assumptions account for the primary factors affecting some of the peak runoff events in North Idaho. However, the timing of our peak runoffs is highly variable (Table 3). Peak flows are not only occurring in the spring. On many streams, peaks are also occurring during the winter, generally as the result of rain-on-snow events. Factors influencing these peaks are much more complex than the snowmelt peaks. Snow accumulation is important, but generally only the snowpack under 4,000 feet contributes to these events (Anderson 1966, Megahan 1972, Harr 1981). Snowmelt is controlled by several factors; but unlike spring snowmelt events, air temperature, wind, and humidity are of primary importance (Anderson 1966, Haupt 1968, Anderson 1969, Harr 1981). Short wave radiation (sunlight) plays only a minor role (Anderson 1966, Megahan 1972, Harr 1981).

Our annual runoff patterns are a hybrid between the dry snowpack, snowmelt relationship of Colorado and the wet snowpack rain-on-snow conditions of the Pacific Norhtwest. Runoff from higher elevation (above 4,000 feet) drainages occurs in the spring and follows the processes described in the model. Peak flows on lower elevation drainages are more complex. Although spring snowmelt peaks occur, winter rain-on-snow peaks are generally much larger and more important in determining channel changes. Hayden Creek is an example (Table 3). Annual peak flows range from 121 to 790 cfs, with an average of 410 cfs. Of the 9 peaks exceeding 410 cfs, 8 were caused by rain-on-snow events occurring between December 15 and March 31. These eight peaks averaged 670 CFS. Spring peaks were significantly lower, averaging 295 CFS. Inspection of the flow records for the other drainages in Table 3 indicates that where a high percentage of the area is under 4,000 feet, factors influencing rain-on-snow events are far more important than those affecting spring snow melt events. Even if we assume that none of the spring peaks are the result of rain-on-snow events, only the upper St. Joe, Priest and Pack Rivers, the Kootenai River tributaries downstream of Bonners Ferry and the Moyie River would fit the spring snow melt projections. All other drainages on the Forest would be primarily influenced by rain-on-snow events.

Due to the complexity of rain-on-snow events, modeling management effects will be difficult. Some of the basic assumptions in the Water Yield Model need to be changed. Wind speed and air temperature rather than short wave radiation would be the primary factors controlling snowmelt. Projected runoff rates and stand recovery rates would have to be changed. Projections of synchronization would also have to be altered to account for these factors. The significance of the snowpack depth under 4,000 feet would be of central importance, while that above this elevation would be a lesser concern.

e. The Analysis Procedure should be based on flow and channel changes in smaller headwater streams rather than larger streams (third, fourth, and fifth orders).

The Water Yield Model and Analysis Procedure has been designated for use on third, fourth and fifth order streams (Isaacson 1977). The field survey, constraints and predictions are all based upon these larger drainages. However, almost all of the studies of water yield and peak flow changes associated with canopy removal have been based on much smaller (first and second order) drainages (Table 2). Bosch and Hewlett (1982) point out that the average size of drainages used in water yield studies has been 198 acres. Extrapolating these results to larger drainages would be unrealistic. Most authors have noted that changes in flows arising from harvest are undetectable in larger streams, and that if channel impacts do actually result from increased flows, they would occur in smaller, headwater drainages (Anderson et al. 1976, Christner and Harr 1982, Troendle 1982, Ponce and Meiman 1983, Harr 1983, Krutilla et al. 1983, Beschta and Froehlich 1983, Christner and Harr 1982, Wilford 1984). Wilford (1984) identifies a maximum watershed size of approximately one square mile for evaluating potential increases in flow.

Section B3 describes several reasons why headwater streams are more vulnerable to flow increases than larger streams.

Table 3. Summary of annual instanteous peak flows (CFS) for some representative drainages (U.S. Geological Survey Data). Underlined flows are winter peaks which are generally associated with rain-on-snow events (before March 31). Some of the spring peaks may also be the result of rain-on-snow events.

	St. Maries R. (at Santa)	St. Joe R. (at Calder)	Hayden Ck.	CDA R. (at Shoshone)	Boulder Ck.	Boundary Ck.
Drainage Area (Square Miles)	275	1,030	22	335	53	97
Drainage area less than 4,000 ft.	Most	Mixture	Most	Mixture	Little	Little
1930		8,510			683	1,020
31		8,790			835	1,320
32		17,400			1,330	1,680
33		19,600			1,330	2,400
34		53,000			1,320	1,760
35		13,400			1,540	1,600
36		20,000			1,100	1,490
37		12,700			920	1,320
38		46,000			2,050	2,270
39		13,800			854	1,400
1940		8,140			760	1,200
41		5,280			1,200	2,300
42		10,400			2,170	1,610
43		14,800			1,170	2,400
44		5,470			488	746
45		15,500			1,080	1,840
46		15,200			1,220	1,970
47		23,600			1,140	1,700
48		23,700	680		2,700	2,530
49		19,200	295		1,340	2,120
1950		18,400	774	9,610	1,770	2,250
51		17,200	600	7,470	1,050	1,620
52		16,200	371	6,900	1,050	1,540
53		13,600	744	6,560	1,220	2,270
54		20,400		5,800	2,040	2,350
55		18,200		7,110	1,360	3,280
56		20,600		7,110	1,660	2,610
57		16,700		6,330	1,320	1,810
58		14,000		6,220	950	1,910
59		15,200	366	5,570	1,320	1,900
1960		13,500		5,890	1,140	1,730
61		15,500		11,000	1,410	3,170
62		16,600	294	8,600	1,120	1,400
63		7,200	196	3,100	952	1,660
64		19,100	206	6,620	1,350	1,970
65		30,400	790	11,900	1,050	1,780
66	1,480	14,400	211	4,880	1,120	1,750
67	1,910	18,200	393	4,920	1,950	2,230

	St. Maries R. (at Santa)	St. Joe R. (at. Calder)	Hayedn Ck.	CDA R. (at Shoshone)	Boulder Ck.	Boundary Ck.
Drainage Area (Square Miles)	275	1,030	22	335	53	97
Drainage area less than 4,000 ft.	Most	Mixture	Most	Mixture	Little	Little
68	4,340	14,000	195	3,610	1,170	3,540
69	3,040	16,600	328	5,810	2,720	2,690
1970	3,190	14,700	423	5,880	1,610	1,850
71	2,040	23,000	160	6,630	2,390	3,000
72	6,290	21,600	770	5,880		2,810
73	1,200	6,500	51	3,110		2,120
74	10,700	33,000	650	22,000	3,140	3.260
75	2,850	16,600	200	6,840	807	1,960
76	3,010	21,600	236	9,600	1,730	2,470
77	780	6,730	24	1,930	579	1,220
78	3,440	18,600	317	4,860	847	1,860
79	5,510	21,000	338	5,940	910	1.430
1980	1,510	12,800	121	3,660	1,280	3,270
81	4,620	24,600	596	10,900		

f. The Stream Reach Inventory and Channel Stability Evaluation needs updating. The original channel stability rating procedure was developed by Megahan (1965) for evaluating channel conditions in southern Utah. Pfankuch (1978) changed this system into the field inventory used with the water yield procedure. The objective of this inventory is to evaluate the resistive capacity of mountain streams to detachment of bed and bank materials due to changes in flow and/or increases in sediment production, and to assess the ability of channels to adjust and recover from these changes (Pfankuch 1975).

The rating system needs updating. The system is too subjective and vulnerable to large variation due to individual interpretation. Individual variability makes channel comparisons difficult and makes the procedure an unreliable monitoring tool.

The rating procedure needs to reinterpret the role of obstructions in the channel and woody material on the banks. The procedure treats these items as contributors to channel instability. However, since the development of the procedure several researchers have noted that instream obstructions are critical components providing stability to the channel (Hewlett and Douglass 1968, Swanson and Lienkaemper 1978, Keller and Swanson 1979, Likens and Bilby 1982, Megahan 1982, Bilby 1984, Heede 1985). Instream obstructions store and stabilize bedload sediment and restrict annual movements which can cause bank erosion. They also reduce the energy of high flows and their ability to cause bank scour. The Little North Fork of the Coeur d'Alene River and Teepee Creek provide examples where adjacent reaches have very different stabilities due to the difference in the relative abundance of woody material in the channels.

Stability ratings have also been misinterpreted. The rating system was developed to provide insight into the potential for increased sediment transport and bank detachment if flows are increased through a channel. However it is not suitable to evaluate the actual "stability" of a channel. Schumm (1971) and Megahan (1979) describe 3 different channel types based upon inherent differences in stream energy and sediment transport conditions. The maximum stability of each channel type occurs under a different set of conditions. Thus, while a width-to-depth ratio of greater than 40 may indicate a stable condition on low gradient, bedload, depositional channels, such a measurement would note an unstable situation on a high gradient, suspended load, erosional channel (Schumm 1971). If all channel types are rated against the same criteria, misleading assessments of actual stability will result. A depositional channel with a width to depth ratio of 20 is not in a stable condition even though it may appear more resistant to bank detachment due to increased flows.

Misuse of the inventory rating system has resulted in damages to fish habitat. Many managers have adopted channel stability as a water resource goal. By managing to improve or maintain the channel stability rating of a stream, they assume a direct relationship to a beneficial use such as fish habitat. Actually, the relationship between channel stability and the needs of beneficial uses is much more complex. For example, a good rating may be desirable if the life span of a stream crossing is the prime concern, but it is undesirable if fish habitat is an objective. In-channel obstructions and replacement material on the banks, gravel beds, channel braids, and undercut banks are all important components of fish habitat which are considered as contributors to unstable channels by the rating system. Thus, use of the rating system to define stream management goals results in the misinterpretation of these key habitat features.

g. Some interpretation based on the Model and Evaluation Procedure need reevaluation and modification to prevent losses to fish habitat quality.

Misuse of the Model and Evaluation Procedure has resulted in damages to fish habitat quality. Additional roads have been constructed and logs have been removed from streams based upon inaccurate interpretations. Where water yield thresholds are a concern, individual tree harvesting has been required. While individual tree harvesting is not a bad recommendation <u>per se</u>, these systems require the construction of many more miles of road to harvest the same timber volume. Because the procedure treats roads like any other opening, partial harvesting with increased road miles has been considered more acceptable than clearcut harvesting with fewer roads. In addition, to avoid projections of runnoff synchronization, more roads have been required to spread the harvest throughout the drainage.

The problem with these recommendations is that most research results indicate road miles pose a greater threat to channel conditions and fish habitat than harvested openings. In addition to possible increases in peak flow, roads also contribute sediment. While the relationship between flow increases and channel conditions may be questionable, the relationship between increased sediment loading and channel conditions is well established. All documented changes in channel conditions have been attributed to increases in sediment load and not higher flows (Beschta 1983, Lyons and Beschta 1983, Hess 1984, Grant <u>et al</u>. 1984). Increased sediment loads have also been responsible for reductions in fish habitat quality (Bjornn 1969, Phillips <u>et al</u>. 1975, Hausle and Cable 1976, McCuddin 1977, Bjornn <u>et al</u>. 1977, Reiser and Bjornn 1979). Because roads are normally the major contributor of sediment resulting from management, alternatives which require more roads are likely more threatening to the channel and fish habitat than those including clearcut harvesting (Anderson 1954, 1966, Anderson et al. 1976, Beschta 1978).

In addition, roads have also been associated with increased peak flows (Harr 1976, 1979, Megahan 1972, 1983). In fact roads may actually be a greater concern than harvest openings because they may increase larger peak events (Harris 1973, Harr 1976, Megahan 1976).

Misinterpretation of the Evaluation Procedure has resulted in the removal of logs from several miles of streams. To improve channel stability, removal of woody material was an annual accomplishment target. Only old material that was deeply embedded and difficult to remove was left.

Unfortunately, these clearing operations have impacted fish habitat. Removal of logs from the channel eliminated most of the trout holding areas (pools), the majority of spawning sites, and the most desirable instream cover. Recent studies have documented the importance of this woody material to stream life, and all have noted severe reductions in habitat quality and fish populations where removal occurred. (Marten et al. 1981, Toews and Moore 1982, Sedell et al. draft, Bryant 1981, Bisson and Sedell draft).

Stream clearing has also resulted in channel instability. The importance of large woody material in stabilizing channels and consequences of its removal are well documented (Swanson and Lienkaemper 1978, Keller and Swanson 1979, Beschta 1981, 1985, Lyons and Beschta 1983, Megahan 1982, 1984, Heede 1985). Removal of the log obstructions released bedload sediment that had been stored and stabilized. This material was then free to shift and move downstream, resulting in bank scour on site and the filling of downstream channels with bedload.

D. ALTERNATIVE EXPLANATIONS FOR OBSERVED "DAMAGES" TO CHANNELS.

Changes in channel conditions and fish habitat quality have lead to water yield concerns. Filling and braiding of channels and bank scour have been attributed to changes in runoff resulting from timber harvest. However, there are several other causes which may be responsible for these channel changes. These causes should also be considered before the assumed cause-and-effect relationship between channel conditions and canopy removal is used to explain existing conditions and changes over time. Otherwise, we may pursue energy consuming strategies of no value or may even aggravate the real cause while trying to eliminate the undesired effect.

The following is a list of well-documented, alternative explanations for changes in third, fourth, and fifth order channels.

1. Riparian Harvest and Removal of Large Woody Material from Channels.

As noted earlier (Section C.2.e.), large woody material plays an important role in storing and stabilizing bedload sediments and in reducing the energy of high flows. Where logs are removed, increased channel erosion should be anticipated. The creation of wide, shallow, relatively unstable channels is a normal consequence.

A reduction in the amount of large woody material in the Forests' streams has occurred. Management has removed large woody material from channels to improve channel stability, maintain fish passage, salvage timber, and protect roads. In 1974 and 1975, the Fernan District alone removed large woody material from over 120 miles of 33 streams (Goodman 1974, Ramsey 1975). Although normally pursued at a lower intensity, these removal projects have been popular for 15 to 20 years.

Riparian harvest, without regard to log recruitment, has also been a standard practice. Harvest has eliminated all mature trees from streambanks or selectively removed dead and dying individuals. Removal of these trees has left the stream without replacements for in-channel logs as they rot or wash-out and made the banks more vulnerable to failure as the root systems decay.

There is almost universal agreement among researchers that these practices would contribute to channel instability (Heede 1977, 1985, Swanson and Lienkaemper 1978, Beschta 1979, Keller and Swanson 1979, Megahan 1982, Likens and Bilby 1982, Swanson et al. 1982, Bilby 1984). Therefore not surprisingly, channels on the Fernan District where log removal was pursued have been some of the most unstable.

2. Stream Channelization Due to Road Location.

In addition to log removal, reaches of several streams have been channelized. Tributaries to the Little North Fork of the Coeur d'Alene River are good examples. Of the 21 major tributaries to the Little North Fork, 13 have roads encroaching on the channel. By straightening channels, road encroachment has increased channel gradients and prohibited adjustments to variations in sediment loading and flows. The result has been an increase in channel erosion and lateral migration. Bedload sediments which had been stored in the banks have been released and channel filling and braiding have occurred in downstream reaches (Megahan 1984).

3. Ice Dams.

Ice dams could cause significant channel changes (Smith 1976). Ice jams may form at stream constrictions, resulting in the ponding of water. Road encroachments, culverts, debris jams and naturally occuring channel constrictions provide an abundance of suitable points for the formation of these dams. Sudden release of the stored water would cause flow increases and channel scour far exceeding those predicted by projected increases in water yield.

4. The Natural Dynamic Nature of Channels.

Stream channels are not fixed entities. Rather, they periodically adjust to a variety of factors. Sediment loading, flow volumes, bank conditions and channel obstructions are all important factors which may change dramatically under natural conditions. As a result, channels undergo periodic readjustment and achieve only temporary periods of equilibrium (Megahan 1979).

Some of the instability witnessed today may be the result of earlier natural events. For example, the bedload sediments released during the 1974 and 1982 floods may still be causing channel instability in some stream reaches (Megahan 1986). Beschta (1983) noted such a delayed effect in the Kowai River. As these flood-induced sediments are either transported or stabilized and stored, greater stability will result. However, decades may be required before the stream will recover to its original configuration (Beschta 1981).

Most interpretations of water yield "damage" have been on residual or glaciated Belt geology streams which experience winter rain-on-snow peaks. However, these interpretations overlook the possibility that due to sediment size, transport capabilities and flow regimes, these streams may tend to have wide shallow channels with significant bank scour even under natural conditions. A large percentage of the sediment transported by these streams is large (2 to 6 inches) and moves very slowly through the system. Movement of largest material (4 to 6 inches) may occur only during peak runoff events and be limited to a few hundred feet of downstream movement every century. Lacking efficient transport, this material tends to accumulate as channel and point bars or may be incorporated into streambanks. Channel bottoms are therefore composed of sediments that are small enough to be shifted by high flows but are large enough and abundant enough to cause the deflection of flows into the streambanks. Where shifting of this material is a regular event, accelerated bank erosion is likely due to the deflection of flows. Bank erosion will result in the addition of more coarse sediment to the channel. A positive feedback system is thereby established which will lead to the creation of wide, shallow channels.

More frequent release of stored sediments and greater bank erosion may occur on streams affected by winter rain-on-snow events. Drainages experiencing winter rain-on-snow events have much greater variability in annual peak flow runoff than drainages that experience predominately spring peaks (Table 3). As a result, equilibriums between sediment storage and transport may be much more variable and short-lived in rain-on-snow channels. Coarse sediments may be shifted regularly unless stabilized by woody material. This shifting would tend to cause the channel scour, filling and widening we observe as damage.

Based on geology and runoff patterns, drainages can be ranked according to their natural vulnerability to channel widening and filling:

> Residual Belts (coarser sediment) > Glaciated Belts > Moderately-Weathered Belts > Granitics > Highly-Weathered Belts (finer sediment).
>
> Winter Rain-on-Snow Peaks (greater variability) > Spring Peak Flows (smaller variability).

5. <u>Early Logging Practices</u>.

From 1910 to 1930 extensive logging occurred throughout much of the Forest (Russell 1979, 1984). Logging involved splash dams and log drives. These operations caused significant channel erosion, widening the banks and releasing stored bedload sediments (Russell 1984). Snagging and clearing operations and riparian harvest would have contributed to the damage.

Some streams may not have recovered from this period. Until coarse sediment is stored or transported, and large woody obstructions accumulate in the channel, continued instability should be expected.

6. <u>Increased Sediment Disposition in the Channel</u>.

Several researchers have noted increased sediment transport to streams because of timber management activities (Rice et al. 1972, Megahan and Kidd 1972, Harr 1981, Grant, et al. 1984). From 2 to 100-fold increases have been observed (Anderson 1954, Copeland 1965, Frederiksen 1970, Brown and Kruygier 1971, Megahan 1975, Anderson et al. 1976, Beschta 1978). Accelerated sediment transport has been associated with road erosion and an increased incidence of mass failures. Lyons and Beschta (1983) noted that landslides originating from roads and clearcuts were 27 and 23 times more frequent, respectively than on forested areas. Similarly, Beschta (1978) noted that most of the mass failures on an Oregon Coastal Range drainage were associated with roads.

As described by equation 2 (Section B.3.), these increases in sediment loading can affect channel conditions. Sediment additions reduce channel capacity and increase the frequency and severity of overbank flooding (Anderson, et al. 1976). By shifting the channel laterally, sediment deposits can cause the undercutting of unstable slopes and the release of formerly stable deposits from the banks (Wilson, et al. 1982, Beschta 1985). As a result, channels become progressively wider and shallower. The extent of the response is determined by the amount of introduced sediment and its size (Lyons and Beschta 1983, Beschta 1985). Coarse bedload sediments may have a greater effect on the channel due to its ability to deflect flows and its slower rate of transport.

Channel changes have been observed where sediment loading has increased. Hess (1984) traced channel erosion on 5 small streams to mass failures and the movement of in-channel woody debris. Fourteen of the seventeen mass failures observed originated from roads or clearcuts. Lyons and Beschta (1983) and Beschta (1983) noted significant channel widening and filling resulting from increased deposition. Where sediment additions did not occur, only minor channel changes were observed. Similar results were reported by Grant _et al._ (1984). They noted that almost all channel changes caused by roads or timber harvest could be traced to pulse increases in sediment. After reviewing the conditions on several Coeur d'Alene River drainages, Megahan (1984) felt that sediment was the most important factor affecting the channels and should be of greatest concern to management.

While there is little evidence connecting increases in discharge to channel changes, accelerated runoff resulting from canopy removal may indirectly affect channels by increasing the incidence and severity of mass failures (Christner and Harr 1982). Landslide hazard is related to the depth of the saturated zone relative to soil depth (Swanston 1967, Ward 1976, Wu and Swanston 1980). Small increases in water delivery during wet periods could be enough to increase the amount of saturation sufficiently to destabilize sensitive soils (Harr 1981, Harr draft, Berris and Harr draft). Furthermore, harvesting eliminates the stabilizing effects of deep rooted vegetation and can reduce the water storage capacity of the soil (Swanston 1974, Anderson, _et al._ 1976, Sidle 1985). Not suprisingly, therefore, a large percentage of management-associated mass failures noted by Grant, _et al_. (1984) and Hess (1984) originated from clearcuts. Although soils on the Idaho Panhandle National Forests may not be as vulnerable as those where there studies were conducted, increased mass failures due to harvesting is still a possibility.

7. Loss of Sediment Storage in Headwater Drainages.

Headwater streams are important storage areas for sediment. Log obstructions on these streams may stabilize 15 to 100 times more sediment than annually delivered to the mouths of drainages (Megahan 1982, 1984). Sudden release of this stored material could overwhelm the transport capacity of downstream stream reaches and cause significant channel adjustments. Recovery of the downstream channels from such heavy loading of bedload sediments could take decades (Beschta 1981).

While the release of this stored material occurs under natural conditions, management activities could increase the frequency and magnitude of these occurrences. Logging can cause the destabilization of the headwater streams by removing or weakening the log obstructions and by reducing the stabilizing effects of woody root systems. Replacement of obstructions may also be eliminated by harvesting trees in the riparian zone. The cumulative effect is a greater potential for mass movements of stored sediments during flood events. As mentioned earlier, "weakened" headwater channels would also be the most vulnerable streams to increased flows due to canopy openings (Harr draft, Megahan 1984).

E. CONCLUSIONS AND RECOMMENDATIONS.

A summary of the major points I have concluded from this review include:

- Channel changes have been caused by sediment additions, removal of large woody material, road encroachment, and riparian harvest. These causes provide better documented explanations of channel changes and should be considered before water yield increases are identified as the primary cause.

- Residual and glaciated Belt drainages experiencing rain-on-snow events are inherently vulnerable to channel widening and filling. Removal of large woody material and road encroachment will likely destabilize these channels regardless of harvest-induced increases in runoff. Examples are available on the Forest which demonstrate these effects.

- The effects of harvest-induced increases in flows on third order and larger streams have been relatively small or undetectable and are probably of minimal concern in regards to channel conditions and fish habitat qulaity.

- If harvest-induced increases in runoff affect third order and larger channels, it is most likely due to the destabilization of headwater streams (wash-out of log structures) or the triggering of mass failures (saturation of sensitive soils). The sediment resulting from these occurrences could significantly change larger channels and degrade fish habitat. The effects of increased flows on headwater channels and sensitive soils needs evaluation and should be the focal point of project evaluations.

- Very little is known on the effects of management-induced changes in flows and sediment on first and second order channels. Clarification of these effects is critical to our understanding of the relationship between upslope management activities and water resources lower in the drainage.

- The relationship between the Water Yield Model and Channel Stability Evaluation Procedure to changes in third order and larger channels is undocumented and questionable. The techniques need updating and better supportive documentation needs to be included. The results should not be used to evaluate changes in fish habitat. Management recommendations which result in more road construction or debris jam removal based on the analysis results are inappropriate and self-defeating in most cases.

- Management to achieve high channel stability ratings as described by the Channel Stability Evaluation Procedure should not be a goal for most streams. The suitability of channel conditions should be defined by management objectives and the needs of benefiting resources and not the rating. A clearer understanding of channel stability and desirable conditions is needed on the Forest. Stability evaluations should be based on channel type.

The following recommendations are provided based on these conclusions.

1. Monitoring and an administrative research study are needed to evaluate the cumulative effects of sediment additions and flow increases on the structure and sediment storage capacity of first and second order streams. Tributary streams are the critical linkage between management activities on the slopes and fish habitat and other beneficial uses in the main stream. The effects of flow increases on sediment transport and storage in these headwater streams is the central question regarding concerns about management-induced increases in flow. Yet we know very little about these effects. Lacking this understanding, controversial management recommendations regarding canopy removal will be based on speculation that will be tough to defend technically. A headwater stream monitoring procedure is described below in Section E.3., below. This work should be supplemented by a more intensive administrative study.

2. We need to evaluate and document channel changes which are suspected of having been caused by management-induced changes in stream discharge. Reviews are needed to document potential causes and to describe watershed conditions when the changes occurred. Factors such as road mileage and condition, sediment sources, land types, sediment loading, harvest acres and age, area of compacted soils, condition of tributary streams, flow history, and riparian and in-channel management need to be evaluated. Based on these reviews some quantifiable cause and effect relationships may emerge that will assist us in evaluating management proposals and in responding to the public.

3. Until we better define timber harvest/runoff relationships, an interim assessment procedure is needed to prevent the loss of desirable channel conditions as a result of cumulative effects of management. The sediment/fish habitat relationships being used to "redflag" proposals should assist us in identifying activities that could damage channel conditions on important fishery streams. However, the relationship between the sediment/fish habitat procedure and bank damage is not well defined and may not be sensitive enough, particularly on the Belt geology drainages.

I do not recommend the use of the Water Yield Procedure to establish thresholds until the inherent problems noted earlier are corrected and better supportive documentation is identified. Rather, I recommend that the analysis procedure described below be adopted until we have a better understanding of relationships.

To improve our understanding of harvest/runoff/channel relationships and to enhance input used to evaluate timber sale alternatives, I recommend a new analysis based upon field surveys. Surveys would be completed on headwater streams (drainage area 1 to 2 square miles) that have or are proposed to have more than 25 percent of their in stands less than 25 years old. Twenty-five percent is based upon "rules of thumb" presented by Toews and Wilford (1978) and Christner (1982) for drainages experiencing rain-on-snow events and on a generalized threshold associated with the Water Yield Model. In addition, drainages in which soil compaction would exceed 5 percent of the baisin should also be surveyed to evaluate the utility of a guideline presented by Harr (1976). The survey would be designed so that objective, quantitative information could be collected for about 2 streams in a day. The following data would be collected for the channel:

1. Width
2. Depth
3. Gradient
4. Bottom materials
5. Minimum diameter of stable bottom materials
6. Number of obstructions
7. Type of obstructions
8. Volume of stored sediment
9. Riparian vegetation

In the short term, the data would be used to evaluate the present condition of the channel and its sensitivity to proposed activities. Over a longer term, the data could also be used to determine if relationships exist between channel conditions and natural settings (stream order, gradient, etc.) or management changes (harvest, road density etc.). I suggest that relationships between channel conditions and the following parameters be evaluated:

1. Stream order
2. Channel gradient
3. Drainage area
4. Major land types
5. Harvest by elevation
6. Road conditions (open/closed/restored)
7. Road Density
8. Riparian harvest

Collection of this data will eventually provide us with a data base that will enhance an understanding of the structure and functioning of headwater channels, clarifying relationships to management, and provide reliable, documentable assessments and recommendations for planning timber sale and road construction activities.

4. The Channel Stability Evaluation needs improvement. Rather than a subjective rating system which ranks channels based on a single set of rating criteria, we need an objective, quantitative assessment that measures critical aspects of channels. Conditions that need quantification are listed above in section E.3.

   Using these measurements, channel conditions should be evaluated based upon the primary resource objective the reach is being managed for. For example, undercut banks would be highly desirable if resident fish habitat is the objective, but would not be as desireable on a site where the longevity of a stream crossing structure is of primary concern. Another example is channel bars and braiding would be very undesirable on a site where maintenance of a stream crossing structure is of primary concern, but would be very compatible as a nursery area for trout or as a sediment storage area serving to protect downstream uses. A unique evaluation is needed to weigh the suitability of channel parameters for each benefiting resource. A single assessment is not suitable.

5. Although this review has dealt primarily with unknowns regarding management's effects on stream channels, there are also several well-documented relationships which should be incorporated into management to reduce the potential of fish habitat losses due to channel damage:

   a. Large woody material is vital to the maintenance of bedload storage and fish habitat. Generally, we should not remove this material from the channel, and we should adopt riparian management prescriptions and guidelines to provide for the replacement of this material in the future. Salvaging and firewood harvesting in the riparian zone inhibit our ability to provide for future log recruitment to channels.

   b. Road encroachment seriously damages fish habitat and many desirable functions of the channel (sediment and water storage, energy reduction, and adaptability to natural changes). Several of our streams have been damaged by this activity. Districts should develop an inventory of roads that enchroach on streams and could be eliminated without restricting future access to timber management lands. Elimination of these roads should be pursued. Future road enchroachment should be avoided.

c. Our management of headwater streams needs to respect their importance in bedload storage and sediment routing. Wood "steps" should not be disturbed during the logging operations and during fireline construction.

Special riparian management guidelines are needed along these streams to provide for replacement of logs as they wash out or rot and to protect trees whose root systems stabilize the channel banks. The guidelines presented in the Forest Plan need to be used and improved upon.

d. Management induced increases in sediment loading have definitely been associated with channel damages. There are several methods available to reduce the likelihood or severity of damages due to sediment. I believe the following items would be particularly beneficial in reducing sediment loading:

- Close roads. Road closure includes blockage of public traffic, waterbarring, seeding of the surface and cut and fill slopes, and perhaps most important, removal of culverts whose failure would result in the erosion of large fills or a section of the road surface. Research in the Northwest indicate that landslide, headwater, and culvert failures are the most frequent causes of channel damages. I believe culvert failures play the major role on our Forest. Failure of culvert crossings is not a possibility but an inevitablity. Large quantities of sediment have been carried to streams from these failures. The quantity of sediment is more than adequate to destablize channels. Because reductions in culvert capacities can occur very rapidly as high flows mobilize material in the floodplain, increased road maintenance would not provide adequate protection.

- Windrow slash on or below road fills at stream crossings. Sediment entry into the stream system occurs primarily at stream crossings. Therefore, if we can control sediment at these points, we could significantly reduce impacts downstream. Filter windrows trap 75 to 85 percent of sediment entering at stream crossings (Cook and King, 1983). In light of this potential, these devices deserve greater attention on this Forest.

- Rolling grades on climbing roads have been very beneficial in reducing surface erosion. During storm runoff, these devices minimize surface erosion and prevent saturation of fills due concentration of drainage water. Present use on the Forest is spotty and could benefit from added emphasis.

- Road drainage is of critical importance. Many mass failures noted on the Forest roads have occurred due to overloading and saturation of fill slopes on outsloped roads or the plugging of ditches and crossover culverts on ditched roads. Adequate design and maintenance are needed to reduce these occurrences. Established guidelines should be used in planning crossover culverts on ditched roads.

- Open roads on schist and granitic soils should be surfaced. Without adequate surfacing, these roads become deeply rutted which causes significant sedimentation due to accelerated surface and mass erosion.

- Slope stability should be considered in locating roads. The Forest has produced maps detailing slope stabilities. These maps should be consulted during road planning. Unstable areas should not be roaded unless special design features are used to assure stability.

- Hot broadcast burns should be avoided during slash disposal and site preparation. Hot fires can alter soil properties increasing the potential for erosion.

REFERENCES

Anderson, H.W. 1952. How will you have your water? Journal of Forestry 50(3):135.

Anderson, H.W. 1954. Suspended sediment discharge as related to streamflow, topography, soil and land use. Trans. Am. Geophys. Union 35:268-281.

Anderson, H.W. 1960. Prospects for affecting the quantity and timing of water yield through snowpack management in California. Proceedings Western Snow Conference. pp.44-50.

Anderson, H.W. 1966. Integrating snow zone management with basin management. In Water Research. Kneese, A.V. and S.C. Smith, eds. John Hopkins Press, Baltimore, Maryland pp.355-373.

Anderson, H.W. 1967. Snow accumulation as related to meteorological, topographic and forest variables in central Sierra Nevada, California. Int. Assoc. Sci. Hydrol. Publ. 76:215-224.

Anderson, H.W. 1969. Snopack management. In Snow. Oregon State University Water Resources Inst., Seminar WR 011.69. pp.27-40.

Anderson, H.W. and C.H. Gleasen 1960. Effects of logging and brush removal on snow water runoff. Int. Assoc. Sci. Hydrol. Publ. 51:478-489.

Anderson, H.W., M.D. Hoover, K.G. Reinhart 1976. Forests and water: effects of forest management on floods, sedimentation, and water supply. USDA Forest Service General Technical Report, PSW-18/1976. 115 pp.

Beaudry, P. and Golding, D.L. 1983. Snowmelt during rain on snow in coastal British Columbia. Paper presented at Western Snow Conference, Vancouver, Washington. 12 pp.

Berris, S.N. and R.D. Harr. Draft. Comparative snow accumulation and melt during rainfall in forested and clearcut plots in western Cascades of Oregon. 30 pp.

Beschta, R.L. 1978. Longterm patterns of sediment production following road construction and logging in the Oregon Coast Range. Water Resources Res. 14(6):1101-1016.

Beschta, R.L. 1979. Debris removal and its effect on sedimentation in an Oregon Coast Range stream. Northwest Sci., 53(1):71-77.

Beschta, R.L. 1981. Management inplications of sediment routing research. In: National Council of the Paper Industry for Air and Stream Improvement, Special Report, Portland, Oregon, May 13-14, 1981. pp. 62-66.

Beschta, R.L. 1983. Long-term changes in channel widths of the Kawai River, Talesse Range, New Zealand, Jour. Hydrol. (N.Z.). 22(2)93-111.

Beschta, R.L. 1985. Conceptual models of sediment transport in streams. Paper presented at Gravelbed River Workshop, August 1985, Pingree Park, Colorado. 36 pp.

Beschta, R.L. and H.A. Froehlich 1983. Review of Idaho Panhandle National Forests Water and Sediment Yield Models. Report to Inland Forest Resource Council, December 1983. 24 pp.

Bilby, R.E. 1984. Removal of woody debris may affect stream channel stability. Journal of Forestry: 609-613.

Bisson, P.A. and J.R. Sedell, Draft. Salmonid populations in logged and unlogged stream sections of Western Washington.

Bjornn, T.C. 1969. Embryo survival and emergence studies. Job No. 5, Federal Aid in Fish and Wildlife Restoration. Job Completion Report Project F-49-R-7. Idaho Fish and Game Department, 11 pp.

Bjornn, T.C., M.A. Brusven, M.P. Molnau, J.H. Milligan, R.A. Klamt, E. Chacho and C. Schaye. 1977. Transport of granitic sediment in streams and its effects on insects and fish. Forestry Wildlife and Range Experimental Station, Completion Rep. Water Res. Inst. Project B-036-IDA. University of Idaho, Moscow. 43 pp.

Bosch, J.M. and J.D. Hewlett 1982. A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. J. Hydrol. 55:3-23.

Brown, G.W. and J.T. Krygier 1971. Clearcut logging and sediment production in the Oregon Coast Range. Water Resources Res. 7(5):1189-1199.

Brendt, H.W. 1961. Some influences of timber cutting on snow accumulation in the Colorado Front Range. Rocky Mountain Forest and Range Experiment Station, USDA Forest Service Res. Note 58. 3 pp.

Brendt, H.W. 1965. Snow accumulation and disappearance in lodgepole pine clearcut blocks in Wyoming. Journal of Forestry 63:88-91.

Bryant, M.D. 1981. Organic debris in salmonid habitat in southeast Alaska; measurement and effects. Paper presented at the Symposium on Acquisition and Utilization of Aquatic Habitat Inventory Information. Portland, Oregon. October 23-28. pp. 259-265.

Chow, V.T., B.S. Barnes, A.J. Polos and others, 1957. Report of the Committee on runoff, 1955-1956. American Geophys. Union Trans. 38:379-384.

Christner, J. 1982. Water resource recommendation for controlling the amount of harvest in a subdrainage. USDA Forest Service, Willamette National Forest Land and Resource Management Planning Background Paper. 18 pp.

Christner, J. and R.D. Harr 1982. Peak streamflows from the transient snow zone, western Cascades, Oregon. Presented at the Western Snow Conference, April 20, 1982, Reno, Nevada. 12 pp.

Copeland, O.L. Jr. 1965. Land use and ecological factors in relation to sediment yields. In Proc. Fed. Inter-Agency Sedimentation Conference 1963. USDA Misc. Publ. 970. pp. 72-84.

Cook, M.J. and J.G. King 1983. Construction cost and erosion control effectiveness of filter windrows on fill slopes. Intermountain Forest and Range Experiment Station, Ogden, Utah. USDA Forest Service Research Note INT-335. 5 pp.

Douglas, J.E. 1967. Effects of species and arrangement of forests on evapotranspiration. In Forest Hydrology. Supper, W.E. and H.W. Lull, eds. Pergamon Press, New York. pp. 451-461.

Frederickson, R.L. 1970. Erosion and sedimentation following road construction and timber harvest on unstable soils in three small western Oregon watersheds. USDA Forest and Range Experiment Station, Portland, Oregon. 15 pp.

Galbraith, A.F. 1973. A water yield and channel stability analysis procedure. Working Paper, Kootenai National Forest, Libby, Montana. 37 pp.

Gary, H.L. and C.A. Troendle 1982. Snow accumulation and melt under various stand densities in lodgepole pine in Wyoming and Colorado. USDA Forest Service Research Note RM 417. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 7 pp.

Gary, H.L. and R.K. Watkins 1985. Snowpack accumulation before and after thinning a doghair stand of lodgepole pine. USDA Forest Service Research Note RM-450. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 4 pp.

Golding, D.L. 1982. Snow accumulation patterns in openings and adjacent forest. In Proceedings Canadian Hydrologic Symposium 82, Fredricton, R.B., June 13-15, 1982.

Golding, D.L. and R.H. Swanson 1978. Snow accumulation and melt in small forest openings in Alberta. Canadian Journal of Forest Research 8(4):380-388.

Goodell, B.C. 1952. Watershed management aspects of thinned young lodgepole pine stands. Journal of Forestry 50(5).

Goodman, R.J. 1975. Flood damage rehabilitation project accomplishments as of January 3, 1975. USDA Forest Service, Region 1, Idaho Panhandle National Forests, Fernan Ranger District, January 1975. 6 pp.

Grant, G.E., M.J. Crozier and F.J. Swanson 1984. An approach to evaluating off-site effects of timber harvest activities on channel morphology. Presented at the Symposium on the Effects of Forest Land Use on Erosion and Slope Stability, May 7-11, Honolulu, Hawaii. 10 pp.

Harr, R.D. 1976. Forest practices and streamflow in western Oregon. USDA Forest Service, Technical Report PNW-49, Portland, Oregon. 18 pp.

Harr, R.D. 1979. Effects of timber harvest on streamflow in the rain-dominated portion of the Pacific Northwest. In Proceedings of a Workshop on Scheduling Timber Harvest for Hydrologic Concerns, USDA Forest Service, Portland, Oregon. 45 pp.

Harr, R.D. 1980. Streamflow after patch logging in small drainages within the Bull Run municipal watershed, Oregon. USDA Forest Service Research Paper PNW-268. 16 pp.

Harr, R.D. 1981. Some characteristics and consequences of snowmelt during rainfall in western Oregon. Journal of Hydrology 53:277-304.

Harr, R.D. 1983. Potential for augmenting water yield through forest practices in western Washington and western Oregon. Water Res. Bulletin 19(3):383-393.

Harr, R.D., 1986. Effects of clearcut logging WRR on a rain-on-snow runoff in western Oregon: a new look at old studies. 22 pp.

Harr, R.D., W.C. Harper, J.T. Krygier and F.S. Hsieh 1975. Changes in storm hydrographs after road building and clearcutting in the Oregon Coast Range. Water Resources Research 11(3):436-444.

Harr, R.D. and F.M. McCorison 1979. Initial effects of clearcut logging on size and timing of peak flows in a small watershed in western Oregon. Water Resources Research 15(1):90-94.

Harris, D.D. 1973. Hydrologic changes after clearcut logging in a small Oregon coastal watershed. Journal of Research U.S. Geologic Survey 1(4):487-491.

Haupt, H.F. 1968. The generation of spring peak flows by short-term meteorological events. Bulletin Int. Assoc. Sci. Hydrol., XIII 4(12):65-76.

Haupt, H.F. 1979a. Local climatic and hydrologic consequences of creating openings in climax timber of north Idaho. Intermountain Forest and Range Experiment Station, Ogden, Utah, USDA Forest Service Research Paper INT-223, 43 pp.

Haupt, H.F. 1979b. Effects of timber cutting and revegetation on snow accumulation and melt in north Idaho. Intermountain Forest and Range Experiment Station, Ogden, Utah, USDA Forest Service Research Paper INT-224, 14 pp.

Hausle, D.A. and D.W. Coble. 1976. Influence of sand in redds on survival and emergence of brook trout. Trans. Am. Fish. Soc. 105(1):57-63.

Heede, B.H. 1977. Influence of forest density on bedload movement in a small mountain stream. In: Hydrology and Water Resources in Arizona and the Southwest, Volume 7:103-107.

Heede, B.H. 1985. Interaction between streamside vegetation and stream dynamics. Paper presented at the Symposium on Riparian Ecosystems and their Management: Reconciling Conflicting Uses, April 16-18, Tucson, Arizona, pp. 54-58.

Hess, S. 1984. Timber harvest and flooding. Journal of Soil and Water Conservation :115-117.

Hewlett, J.D. and J.E. Douglas 1968. Blending forest uses. Southeast Forest Experiment Station, Ashville, North Carolina, USDA Forest Service Research Paper SE-37, 15 pp.

Hewlett, J.D. and J.D. Helvey 1970. Effects of forest clear-felling on the storm hydrograph. Water Resources Research 6:768-782.

Hewlett, J.D. and A.R. Hibbert 1967. Increase in water yield after several types of forest cutting. Int. Assoc. Sci. Hydrol. Bulletin 6(3):5-17.

Hoover, M.D. and C.F. Leaf 1967. Process and significance of interception in Colorado subalpine forest. In: Forest Hydrology. W.E. Sopper and H.W. Lull eds. International Symposium Forest Hydrology, University Park, Pennsylvania, August-September 1967. Pergamon Press, New York, New York, 813 pp.

Isaacson, J.A. 1977. A computer model for determining water yield from forest activities, IPNF*LIB.H2OY 1977 version. USDA Forest Service, Idaho Panhandle National Forests, Coeur d'Alene, Idaho, 36 pp.

Keller, E.A. and F.J. Swanson 1979. Effects of large organic material on channel form and fluvial processes. Earth Surface Processes 4:361-380.

King, J.G., Draft. Streamflow response to roading and harvesting: a companion with the equivalent clearcut model. Intermountain Research Station, Ogden, Utah, USDA Forest Service Research Paper, 17 pp.

Kittredge, J. 1953. Influence of forests on snow in the ponderosa-sugar pine-fir zone of the central Sierra Nevada. Hilgardia 22:1-96.

Krutilla, J.V., M.D. Boves and P. Sherman 1983. Watershed management for joint production of water and timber: a provisional assessment. Water Resources Bulletin 19(3):403-414.

Leaf, C.F. 1975. Watershed management in the Rocky Mountain subalpine zone: the status of our knowledge. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USDA Forest SErvice Research Paper RM-137, 31 pp.

Leopold, L.B., M.G. Wolman and J.P. Miller 1964. Fluvial processes in geomorphology. W.H. Freeman and Company, San Francisco and London, 522 pp.

Likens, G. E. and R.E. Bilby 1982. Development, maintenance, and role of organic-debris dams in New England streams. In: Sediment Budgets and Routiong in Forested DRainage Basins (F.J. Swanson, R.J. Janda, T. Dunne and D.N. Swanston, ed.). USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Gen. Tech. Rep. PNW-141. pp. 122-128.

Lull, H.W. and K.G. Reinhart 1967. Increasing water yields in the northeast by management of forested watersheds. National Forest Experiment Station, Upper Darby, Pennsylvania. USDA Forest Service Research Paper NE=66.

Lyons, J.K. and R.L. Beschta 1983. Land use, floods, channel changes: upper Middle Ford Willamette River, Oregon (1936-1980). Water Resources Research 19(2):463-471.

Martin, D.J., E.O. Salo, S.T. White, J.A. June, W.J. Foris and G.L. Lucchetti 1981. The impact of manged streamside timber removal on cutthroat trout and the stream ecosystem. Final Report. Fisheries Research Institute, University of Washington, Seattle.

McCuddin, M.E. 1977. Survival of salmon and trout embryos and fry in gravel/sand mixtures. M.S. Thesis, University of Idaho, Moscow. 30 pp.

Megahan, W.F. 1965. An approach toward a comprehensive hydrologic analysis. In: Water, Utah's Future. Tech. Proc. Annual Meeting, Utah Chapter Soil Conservation Society of America, January 15, 1965, Salt Lake City, Utah.

Megahan, W.F. 1972. The effects of deforestation and reforestation on streamflow rates in the western United States. Presentation at the Symposium on the Effects of Land Uses on Streamflow, National Meeting of the American Geophysical Union, Washington, D.C., April 23, 1970. 22 pp.

Megahan, W.F. 1975. Sedimentation in relation to logging activities in the mountains of central Idaho. In: Present and prospective technology for predicting sediment yields and sources: Proc. Sediment Yield Workshop, USDA Sediment Lab, Oxford, Mississippi, November 28-30, 1972. USDA Research Service Rep. ARS-S-40. pp. 74-82.

Megahan, W.F. 1976. Effects of forest cultural treatments upon streamflow. In: The Forest Acts Dilemma Symposium, 1975. Proc. Montana Forest and Conservation Experiment Station, University of Montana. pp. 14-34.

Megahan, W.F. 1979. Channel stability and channel erosion processes. Presented at the Workshop on Schduling Timber Harvest for Hydrologic Concerns, Portland, Oregon, November 27-29, 1979. 18 pp.

Megahan, W.F. 1982. Channel sediment storage behine obstructions in forested drainage basins draining the granitic bedrock of this Idaho Batholith. In: Sediment budgets and routing in forested drainage basins (F.J. Swason, R.J. Janda, T. Dunne, and D.N. Swanston, ed.). USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Gen. Tech. Rep. PNW-114-121.

Megahan, W.F. 1983. Hydrologic effects of clearcutting and wildfire on steep granitic slopes in Idaho. Water Resources Research 19(3):811-819.

Megahan, W.F. 1984. Fishery habitat and channel sediment problems in the Coeur d'Alene drainage. Memorandum to William E. Morden, Supervisor, Idaho Panhandle National Forests, August 20, 1984. 4 pp.

Megahan, W.F. 1986. Evaluation of hydrologic problems on Wolf Lodge Creek. Memorandum to William E. Morden, Supervisor, Idaho Panhandle National Forests, April 14, 1986. 3 pp.

Megahan, W.F. and W.J. Kidd 1972. Effects of logging and logging roads on erosion and sediment deposition from steep terrain. Journal of Forestry 70(3):136-141.

Neilson, D.R. 1974. Sediment transport through high mountain streams of the Idaho Batholith. Mater's Thesis, University of Idaho, College of Agriculture, College of Engineering, Department of Agricultural Engineering. 83 pp.

Pfankuch, D.J. 1975. Stream reach inventory and channel stability evaluation, a watershed procedure. USDA Forest Service, Northern Region. 26 pp.

Phillips, R.W., R.L. Lantz, E.W. Claire and J.R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Trans. Am. Fish. Soc. 104(3):461-466.

Ponce, S.L. and J.R. Meiman 1983. Water yield augmentation through forest and range management--issues for the future. Water Resources Bulletin 19(3):415-419.

Ramsey, C.J. 1974. Flood damage stream rehabilitation project accomplishments, January-December 1970-1975. USDA Forest Service, Region One, Idaho Panhandle National Forests, Fernan Ranger District. 7 pp.

Reiser, D.W. and T.C. Bjornn. 1979. Habitat requirements of anadromous salmonids. In Influence of Forest and Rangeland Mangement on Anadromous Fish Habitat in Western United States and Canada. W.R. Meehan, Editor. USDA Forest Service General Technical Report. PNW-96. 54 pp.

Russell, B. 1974. Swiftwater People. Lacon Publishers, Harrison, Idaho. 408 pp.

Russell, B. 1984. North Fork of the Coeur d'Alene River, Lacon Publishers, Harrison, Idaho. 440 pp.

Reinhart, K.G., A.R. Eschner and G.R. Trimble, Jr. 1963. Effect on streamflow of four forest practices in the mountains of West Virginia. Northeastern Forest Experiment Station, USDA Forest Service Research paper NE-1.

Rice, R.M., J.S. Rothacher and W.F. Megahan 1972. Erosional consequences of timber harvesting--an appraisal. In: Proc. Symposium on Watersheds in Transition, Fort Collins, Colorado, June 19-21, 1972. Water Resources Association Series 14. pp. 321-329.

Rothacher, J. 1965. Snow accumulation and melt in strip cuttings on the west slopes of the Oregon Cascades. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. USDA Forest Service Research Note PNW-23. 7 pp.

Rothacher, J. 1970. Increases in water yield following clearcut logging in in the Pacific Northwest. Water Resources Research 6:653-658.

Rothacher, J. 1971. Regimens of streamflow and their modification by logging. In: Symposium Forest Land Use and Stream Environment Processes, Oregon State University, Corvallis, Oregon. pp. 40-54.

Rothacher, J. 1973. Does harvest in west slope Douglas-fir increase peak flow in small forest streams? Pacific Northwest Forest and Range Experiment Station, Portlant, Oregon, USDA Forest Service Research Paper PNW-163. 13 pp.

Satterlund, D.R. and A.R. Eschner 1965. Land use, snow and streamflow regimen in central New York. Water Resources Research 1:397-405.

Satterlund, D.R. and H.F. Haupt 1972. Vegetation management to control snow accumulation and melt in the norther rocky mountains. In: National Sumposium on Watersheds in Transition, 1972. pp. 200-205.

Schumm, A. 1971. Fluvial geomorphology: the historical perspective. In: River Mechanics, Volume I. H.W. Shen ed. Fort Collins, Colorado. pp. 4-30.

Sedell, J.R., F.J. Swanson and S.V. Gregory, Draft. Evaluating fish response to woody debris. 24 pp.

Sidle, R.C. 1985. Factors influencing the stability of slopes. Pacific Northwest Forest and Range Experiment Station, Juneau, Alaska, USDA Forest Service General Technical Report 180. pp. 17-25.

Smith, D.G. 1976. River ice processes: thresholds and geomorphologic effects in northern and mountain rivers. In: Geomorphology and Engineering, D.R. Coates ed. Dowden, Hutchinson and Ress, Inc., Stroudsburg, Pennsylvania. pp. 323-343.

Smith, J.L. 1980. Vegetation - snowpack relations. Presentation at Snowpack Management and Hydrology Training Session, South Lake Tahoe, Calif., October 6-10. 38p.

Swanson, F.J. and G.W. Lienkaemper 1978. Physical consequences of large organic debris in Pacific northwest streams. In: Proc. Logging Debris in Steams II, Workshop, Oregon State University. 28 pp.

Swanson, F.J., S.V. Gregory, J.R. Sedell and A.G. Campbell 1982. Land-water interactions: the riparian zone. In: Analysis of Coniferous Forest Ecosystems in the Western United States (R.L. Edmonds, ed.). US/IBP Synthesis Seven 14. Hutchinson Ross Publishing Company. Stroudsburg, Pennsylvania. pp. 267-291.

Swanson, R.H. and D.L. Golding 1982. Snowpack management on Marmot Watershed to increase late streamflow. In: Proceedings 50th Annual Meeting Western Snow Conference, April 19-23, 1982, Reno, Nevada, Colorado State University, Fort Collins, Colorado.

Swanston, D.N. 1967. Soil water piezometry ina southeast Alaska landslide area. Northwest Forest and Range Experiment Station, Portland, Oregon. USDA Forest Service Research Note PNW-68. 17 pp.

Swanston, D.N. 1974. Slope stability problems assicated with timber harvesting in mountainous regimens of the western United States. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, USDA Forest Service General Technical Report PNW-21. 14 pp.

Toews, D.A.A. and D. Wilford 1978. Watershed management considerations for operational planning on T.F.L. #39 (Blk. 6A), Graham Island. Canada Department of Fisheries and Oceans, Fisheries and Marine Service Manuscript Report No. 1473. 32 pp.

Toews, D.A.A. and M.K. Moore 1982. The effects of three steamsite logging treatments on organic debris and channel morphology of Connection Creek. Land Management Report 11. 29 pp.

Troendle, C.A. 1982. The effects of small clearcuts on water yield from the Deadhorse watershed, Fraser, Colorado. In: Proceedings of the 50th Annual Meeting of the Western Snow Conference, Reno, Nevada, April 19-23, 1982, Colorado State University, Fort Collins, Colorado. pp. 75-83.

Troendle, C.A. 1983. The potential for water yield augmentation from forest management in the Rocky Mountain Region. Water Resources Bulletin 19(3):359-373.

Troendle, C.A. 1986. The effect of timber harvest on the water balance of the subalpine forests. In: Proceedings of Society of American Foresters Hydrology Working Group Technical Session, July 28-31, 1985, Colorado State University, Fort Collins, Colorado. 5 pp.

Troendle, C.A. and C.F. Leaf 1980. Hydrology, Chapter III. In: An approach to water resources evaluation of non-point silvicultural sources. EPA 60018-80-012. Environmental Research Laboratory, Athens, Georgia. 173 pp.

Troendle, C.A. and J.R. Meiman 1984. Options for harvesting timber to control snowpack accumulation. In: Proceedings of the 52nd Annual Western Snow Conference, Sun Valley, Idaho, April 17-19, 1984, Colorado State University, Fort Collins, Colorado. pp. 86-97.

Troendle, C.A. and R.M. King. 1985. The effect of timber harvest on the Fool Creek Watershed--30 Years Later. Water Resources Research. p 1915-1922.

Troendle, C.A. and R.M. King. In press. The effect of partial and clearcutting on stream flow at Deadhorse Creek, Colorado. Journal of Hydrology.

Verry, E.S. 1972. Effect of aspen clearcutting on water yield and quality in northern Minnesota. In: National Symposium on Watersheds in Transition Proceedings, American Water Resource Association, Urbann, Illinois. pp. 276-284.

Ward, T.J. 1976. Factor of safety approach to lanslide potential delineation. Ph.D. dissertation, Colorado State University, Fort Collins, Colorado.

Weitzman, S. and R.R. Bay 1959. Snow behavior in forests of northern Minnesota and its management implications. Lake State Forest Experiment Station, USDA Forest Service Paper 69. 18 pp.

Wilford, D.J. 1984. A proposed forest hydrology decision making strategy for rate of cut. Canada Ministry of Forests, Smithers, British Columbia. 31 pp.

Wilm, H.G. and E.G. Dunford 1948. Effect of timber cutting on water available for stream flow from a lodgepole pine forest. USDA Technical Bulletin 968. 43 pp.

Wilson, D., R. Patten and W.F. Megahan 1982. In: Leachrates: terrain analysis. National Academy of Science, National Research Council, Transportation Research Board, Transportation Research Record 892. pp. 50-56.

Wu, T.H. and D.N. Swanston 1980. Risk of landslides in shallow soil and its relation to clearcutting in northeastern Alaska. Forest Science 26(3):445-510.

Ziemer, R.R. 1964. Summer evapotranspiration trends as related to time after logging at high elevation forest stands in Sierra Nevada. Journal of Geophys. Res. 69(4). pp.615-620.

APPENDIX

Wu, T.H. and D.N. Swanston 1980. Risk of landslides in shallow soil and its relation to clearcutting in northeastern Alaska. Forest Science 26(3):445-510.

Ziemer, R.R. 1964. Summer evapotranspiration trends as related to time after logging at high elevation forest stands in Sierra Nevada. Journal of Geophys. Res. 69(4). pp.615-620.

APPENDIX

United States Department of Agriculture | Forest Service | Idaho Panhandle National Forests | 1201 Ironwood Drive
Coeur d'Alene, ID 83814

REPLY TO: 2630 Fisheries Management

DATE: May 13, 1985

SUBJECT: Effects of Vegetative Management and Road Building on Water Quality

TO: Bob Rainville thru Bob Shackelford, Staff Officer, Multi-Resources

KB

The Idaho Panhandle National Forest(s) is involved in a continuing debate regarding the effects of vegetation manipulation and road building on water quality, water yield, and fish habitat (the primary beneficial use). While the Forest Plan draft has incorporated use of a sediment model, no good account or modeling of water yields are evident in the document. A good deal of concern exists regarding resource management effects on water yields.

The Forest is poised to make significant investments in stream monitoring, restoration/mitigation of watersheds, timber sales, and roadbuilding. We must, I believe, make every effort to assure that our resource managers and the Forest Management Team have a common understanding of the water yield-fishery relationship in light of state-of-the-art technology.

Toward that end, I am asking Bob Rainville to prepare an analysis (white paper) dealing with the effects of increased water yields and peak flows on fish habitat. The analysis should evaluate fisheries implications based on applicable research studies and monitoring that has been performed. I would also like Bob to suggest management objectives and guidelines that will protect and/or improve fish habitat, as well as a recommended monitoring program which will facilitate the implementation and required monitoring of the final Forest Plan.

To mesh with final write-up of the Forest Plan and the start of the fiscal year 1986, I would like Bob's analysis to be completed near October 1, 1985. I would encourage critical review of the analysis by agency specialists, forest users, wildland managers, and educators prior to final drafting.

Ronald C. Prichard
RONALD C. PRICHARD
Deputy Forest Supervisor

cc: Forest Management Team Members.

Department of
Forest Engineering

Oregon State University

Corvallis, Oregon 97331

June 26, 1986

Bob Reinville
USDA Forest Service
Idaho Panhandle National Forest
1201 Ironwood Drive
Coeur d'Alene, ID 83814

Dear Bob:

Enclosed is your draft paper. Reading it was a real breath of fresh air. You obviously have a talent for taking research results (which often have obscure conclusions) and summarizing them clearly and coherently. I think you've done a super job.

As you go through the copy, you'll find most of my comments to be fairly minor. Should you have any questions regarding my comments, please get in touch.

I liked all of what you did, but in particular I liked your recommendation number 5 (a through d). It should be mandatory reading for all foresters and road engineers on the Forest.

When you get the paper revised and in final form, I would greatly appreciate receiving a copy. It's a document that would be very useful in our teaching program at OSU. I would encourage you to send a final copy to Gerry Swank, Regional Hydrologist R-6.

Thanks for the opportunity to review your efforts. I wish you well in changing the way things are done on your Forest. If I can be of further assistance, please let me know.

Sincerely,

Bob

Robert L. Beschta
Acting Department Head

lb

Enclosure

United States Department of Agriculture
Forest Service
Pacific Northwest Research Station
Forestry Sciences Laboratory
3200 Jefferson Way
Corvallis, OR 97331

JUN 30 1986

Reply to: 1630

Date: June 26, 1986

Robert Rainville
Idaho Panhandle National Forest
1201 Ironwood Drive
Coeur d'Alene, ID 83814

Dear Bob:

I have just finished reading your paper on water yields, peak flows, and fish habitat. I want to commend you for an excellent product. I agree with your conclusions, and your pursuasive, well-documented arguments will be hard for anyone to challenge. I really appreciate your fortitude for suggesting that we discard models (Water Yield Model) and analytical procedures (Channel Stability Rating) that don't work, and opt for procedures that are data-based rather than built on untested assumptions. Your literature review is terrific, and I would like to keep the paper for my own library. I did not make any editorial comments or suggestions on the paper.

Again, Bob, a very excellent paper! Thanks for the chance to look at it.

Best regards,

Fred

FRED H. EVEREST
Acting Project Leader
Anadromous Fish Habitat Research

Department of Forest Engineering
Oregon State University
Corvallis, Oregon 97331

July 1, 1986

Mr. Robert Rainville
USDA Forest Service
1201 Ironwood Drive
Coeur d'Alene, ID 83814

Dear Bob:

Thank you for the opportunity to review your analysis on the effects of management-induced increases in water yields and peak flows on fish habitat.

I have made numerous notes in the margins of your draft report. If any of these brief comments are not clear please call and let me clarify them. I have also made partial copies of 17 items (to avoid having to copy large quotes) which will illustrate the point I was trying to make in the marginal notes.

A major difficulty arises in trying to interpret research results on small plots to commercial scale forest management. An even greater problem occurs when the harvest in the research project is designed to maximize snow accumulation. I believe you should make a clearer statement concerning this at the beginning of section B.1. Later when you discuss the longevity of the effect you take the long intervals given for the narrow strips as though they applied to larger units. You discuss these narrow strip cuts and small patches in some detail, but do not give much time to the studies involving larger units.

Earlier work on interception has been markedly revised over the years, yet your literature review treats them all alike. This may be due to your goal of keeping this paper relatively brief, but the management team will not be able to discriminate among these observations.

I believe you should preface section 2 (p. 14) with a clear statement of what peak flows you want to discuss and then be careful to identify the nature of the peaks included in any given study. If the annual peak flow (largest instantaneous flow in cfs in each year) is not increased then the changes in low to moderate peaks seem unimportant and not likely to be damaging to the channel. I agree with your observation that none of the studies show that the measured increases in flow are related to channel damage (p. 21). The quality of logging and road building and maintenance is of overriding importance.

I don't have some of the publications you cite so I cannot comment on the quality or relevance of some of the research (for example Wilford, 1984 and Harr, draft) but I think it is important to identify a research result as separate from a generalized opinion.

On page 52, you mention that "little is known of the effects of management-induced changes in flows and sediment on first and second order channels." I don't agree. A considerable number of studies you reviewed were on first and second order channels. While there have been measured, short-term increases in sediment (usually due to roads or extreme slash burning), none of the studies describe serious channel degradation.

I believe your opening statement on page 3 paints an unnecessarily bleak picture. In the Alsea study where an 18" increase in water yield, an increase in water temperature and an increase in sediment load (extreme slash burning), all resulted in an increase in biomass of coho salmon with an increased net production 1.78 times that of pre-logging period. Similarly, the study by Sedell, et al. on Mack Creek found greater cutthroat trout production following clearcutting, debris removal, and slash burning. The Carnation Creek Study in British Columbia found increased densities of coho fry (fish/m^2) of 1.47 times the pre-logging average. The Nashwaak Exp. Watershed Project reports that brook trout populations were higher following cutting without a bufferstrip.

Stefanich's work on Pinkham Creek, Montana states, "Logging operations have continued and 1,180 acres of land were cut from a 5 to 95 percent cut. There was a slight increase of both total number and total weight of all trout captured." Also, Edgington's study in northern Idaho including clearcutting and selective logging found an impact on stream ecology but concluded, "There was no apparent effect on trout populations." Grette's work in western Washington showed that streams clearcut from 12 to 39 years ago had 1.35 times the coho fry production as streams in old growth. Streams in areas clearcut from 42 to 64 years ago had 3.02 times the coho fry production. Narver (1972) reported that the standing stock of trout was considerably greater in some forested streams than in logged areas, but coho and steelhead were 1.5 times as numerous in the logged area.

Most of these studies show some of the changes in stream conditions which you identify as "damage." It appears to me that there is a serious need to identify those practices and conditions which are truly damaging.

I urge you to insert under item 2, p. 53 (or elsewhere) a comment on the need to determine the actual effect of forest management, including roads, on fish production.

I think you have done a fine job in pulling a large amount of research work together and with some modifications this should be a very helpful review for your management teams. I believe your recommendations (p. 52-59) are sound and should be incorporated, especially if local validation can be accomplished for the last paragraph of item 3, p. 54.

Sincerely,

Henry A. Froehlich

Henry A. Froehlich
Professor

lb
Encl.

To: Mike Johnson

Subject: Comments to draft of Bob Rainville's water yield paper

General Comments:

1) I agree with much of what is presented in the paper, although considerable fine tuning tuning could be done.

2) I felt the tone was somewhat targeted toward criticizing the procedure. This could be cleaned up with some wording changes that I feel would improve the final product.

Specific Comments (presented as they appear in the paper):

1) The paper does not discuss research done by James Smith at the Central Sierra Snow Lab. One item that this research pointed out which others have not was the development of ice lenses in openings which may lead to faster runoff during a rain-on-snow event. I sent Bob a summary paper of this research.

2) The paper should discuss the possibility of increased potential for debris torrents in headwater channels due to increased peak flows and changes in soil moisture status. This is brought up later (section C,2,d), but should probably be addressed in section B, also. In light of Jack King's findings of up to 75% increase in peak flows in 1st order channels, I feel this could be a significant process.

3) The paper should also discuss the implications of Walt Megahan's recent observations of head cutting of stream channels following harvesting and broadcast burning at Silver Creek.

4) Under "strong points" (section C,1,c), the point about moderation of activities within a watershed is a good one. I feel the procedure has helped focus attention on watersheds as a logical unit in project planning. Scheduling and placement of activities is a key component in watershed management.

5) Under "weak points" (section C,2,c), I agree that instaneous peak flows are more important in affecting channels than monthly or annual flows. However, I have some problems with the idea that a 1 to 2-year return interval is the flow which is best related to channel capacity. Whereas, this may hold in many cases, there appear to be situations in which longer return interval flows are more important.

6) Under "weak points" (section C,2,d) and in Table 3, it is indicated that a difference in average elevation exists between Boulder Creek and Boundary Creek. This should be checked out. I believe one would find that the average elevation is similar. The difference in frequency of mid-winter floods may be due to other factors such as the topography directly upwind of these watersheds.

7) Under "weak points" (section C,2,e) it is stated that the channel stability rating is not related to beneficial uses and should not be used as a management goal. This may not always be true. I can conceive of situations where channel stability may be a goal.

8) Under "weak points" (section C,2,g) it is stated that questionable management practices have resulted from the model. I do not question that this is the case, but I feel this is less the fault of the model than of those who would make management decisions based solely on a model without taking into account other factors and tradeoffs.

9) Under "weak points" (section C,2,h) it is stated that stream survey and analysis are time consuming. This is true, but the average time is probably much less than stated. Physical channel surveys should be done in conjunction with fisheries surveys in which case very little extra time would be involved. The amount of time to run the analysis will vary widely depending on how much previous quality information is available for a particular watershed.

10) I agree with most of the recommendations provided at the end of the paper. It should be noted that the Clearwater National Forest procedure (WATBAL) does contain a water yield component in addition to sediment yield.

Nick Gerhardt
7/86

United States Department of Agriculture
Forest Service
Pacific Northwest Research Station
Forestry Sciences Laborato
3200 Jefferson Way
Corvallis, OR 97331

Reply to: 1630

JUN 23 1986

Date: June 19, 1986

Bob Rainville
Idaho Panhandle National Forests
1201 Ironwood Dr.
Coeur d'Alene, ID 83184

Dear Bob:

I'm returning the draft of your anaylsis of management-induced impacts on water yield and peak flows. Most of my comments are scribbled in the margins. Overall, I think it's a well thought out, well-written, and much needed analysis of the peak flow issue and critique of present procedures for analyzing management impacts. I've had the feeling for some time that on this issue, the administrative tail (in the form of a need for a documentable 'process' for evaluating management impacts at a basin scale) has been wagging the scientific dog. You make a good case for why current assessment methodologies are not technically defensible.

I also agree with your conclusions that, at this stage of our understanding, peak flow increases do not appear to be a significant cause of channel changes in large-order streams, and that increased sediment delivery, particularly through accelerated mass-wasting, is a more important issue. However, I think the jury is still out on this whole issue of off-site effects. There may be physiographic regions where peak flow increases <u>are</u> important. I'm currently working on a paper in which I attempt to define the channel conditions under which peak flow increases of the kind that have been reported might be significant in terms of increased frequency of bedload entrainment. I'll send you a copy when it's done.

I also agree that we need to focus attention on dynamics of low-order channels, particularly in terms of looking at the frequency and mechanisms of debris flow initiation. However, evaluating off-site impacts requires that we take a basin-wide perspective. Debris flows which initiate in first-order streams have the potential to move through second- and third-order streams and may ultimately come to rest in higher-order streams. Different types of channel changes may accompany initiation, transport, and deposition phases. One manifestation of peak flow increases (although difficult to document) may be that debris flows experience greater run-out distances due to higher water volumes at time of initiation.

Anyways, I think you've done a good job of laying out the issues. Let me know if I can be of any further assistance.

Sincerely,

Gordon Grant

Gordon Grant
Research Hydrologist

United States Department of Agriculture
Forest Service
Forestry Sciences Laboratory
3200 SW Jefferson
Corvallis, Oregon
97331

Refer to: 2630

JUN 23 1986

Date: June 19, 1986

Subject: Effects of Management-Induced Increases in Water Yields and Peak Flows on Fish Habitat

To: Bob Rainville
Idaho National Forest
1201 Ironwood Drive
Coeur d' Alene, ID 83814

I completed my review of your analysis of the harvest/water/fish habitat situation. I think you have done a commendable job bringing together a wide range of information from research as it relates to the situation on the Panhandle Forest. Your paper is generally well written and conveys several major points without the reader having to muddle through a bunch of technical hocus pocus. And it provides a considerable technical basis for the major points you have made.

I think you have correctly identified the strengths and weaknesses of the Water Yield Model and Channel Stability Analysis. Even more importantly, your description and emphasis of the other possible causes for channel damage is very thorough and should be useful in putting possible causes of observed channel damage in proper order of importance or relative probability of causing the damage. This should help identify what the problems really are with respect to channel stability and identify the best solutions to those problems.

You will find some editorial markings on the manuscript itself. I hope these and my questions and comments are helpful.

Once again, I think you did an excellent job putting this analysis together. Let me know if I can be of further help.

R. Dennis Harr

R. DENNIS HARR
Supervisory Research Hydrologist

Enclosure

United States Department of Agriculture

Forest Service

Intermountain Station

316 East Myrtle Street
Boise, ID 83702

Reply to: 2630

Date: June 26, 1986

Subject: Review of report on "Effects of management-induced...".

To: Bob Rainville
Idaho Panhandle N.F.

Thanks for the opportunity to review your report. You have done a commendable job of reviewing the literature on a very complex set of problems. I have included my comments directly on the text. For the most part, my comments are minor and should all be self explanatory. Don't hesitate to call if you have questions. Please note that I did <u>not</u> check the references against the text citations.

WALTER F. MEGAHAN
Research Hydrologist

BOB:

Appreciated the opportunity to review your "review." Unfortunately, it had a prejudiced tone throughout which may have limited you an opportunity to make a more positive contribution. It sure enough worked to polarize me and to get me on my philisophical band wagon.

Why we let managers get us Technical Specialists into these "No Win" situations is beyond me. It's easy to tell them what they want to hear - But there's a great deal more to the story.

If your goal is to shoot down models you have a long line to stand in.

A shorter line exists for those who recognize advantages of applying models but realizing they fall short of "truth", but keep trying to improve on the model, revise and replace with better process tools.

The long line is easier to find and you'll have a lot of company - But does it really get you anywhere?

My suggestions:

Bring the flow model up to date, with WRENNS, HYSED II or other similar models to meet some initial limitations and utilize some of the on-site hazard/evaluations of Wilson. Combine as many physical process related models you can to help the manager avoid environmental damage. Just because all is not known about flow related models - is the last solution ignoring the stream flow change potential totally? You have the managers attention by at least looking at these processes---so take advantage of it---improve on what you got and start <u>Monitoring</u> to make the evaluation - not taking cheap shots at an indexing model. Help it along - improve on it, combine processes so all influences are looked at. You made great suggestions at the end - these should not be made at the expense of a flow model - but rather interrelated with it.

My suggestion is to shitcan this review and replace it with a positive solution to improve the existing flow model and include your additional suggestions on roads, debris, encroachment, etc which are all good. Pick pieces from Wilson's and others which fit the conditions, rather than say...We'll use the "Clearwater" procedure or the R-6 procedure, or the original R-1. Combine and fit the pieces which you have discovered from your review into a "State-of-the-Art improvement procedure for North Idaho. But <u>don't</u> talk yourself into ignoring flow (energy) related impacts. You may have some rusty parts--But don't cast them aside--Polish or replace and keep the Damn Motor running!

Start integrating the biological processes with stream morphology instead of trying to fit a "channel stability" interpretation different than it was intended.

Show where it's compatible and where it isn't and adjust accordingly. "As soon as I had the answers they changed the question."

Keep the evaluation tools dynamic to fit the question--But don't lose sight of Basic Physical processes, (including flow).

Go back to the manager and tell him--we will gain no more from nit-picking models--what we need is a monitoring program that will give us those answers to the questions you posed in your review. Put the Buck back on them--to where it belongs. If they have any resource (stream) ethic they better start putting some higher priorities on monitoring these streams...so 15 years from now another specialist isn't speculating why <u>you</u> were wrong and why <u>he</u> doesn't like <u>your</u> model... of course, he doesn't have any data so...and but,...In the meantime--Keep simulating potential impacts from process-related models!

Sorry for the abrupt and direct review, the Forest Service never sent me to charm school--These are my thoughts--noone else's.

Dave Rosgen

P.S. Take some time to read EPA-FS "W.R.E.N.S.S.--1980.